APPENDIX C

FOREST MANAGEMENT MODELING

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1.   BASIC PRINCIPLES

This document describes the techniques used to model forest management and harvest schedules for state trust lands within the South Puget Habitat Conservation Plan (HCP) Planning Unit. This computer modeling was undertaken to determine the management necessary to achieve economic, ecological, and social objectives within defined constraints, while simultaneously providing a sustainable yield of forest products and values. The following three components were developed for the computer modeling:

(a) Area database: A user-defined classification system is applied to the forested land base. A Geographic Information System (GIS) is then used to spatially delineate and report the area of the land base in each class or groups of classes. Spatially discontinuous areas with the same unique combination of classes are calculated and reported separately for the modeling purposes.

(b) Yield: Growth and yield modeling is used to generate stand level yield tables showing various forest attributes and how they change during stand development. An array of yield tables is provided to predict stand condition and outcomes under a wide range of silvicultural management regimes. A range of silvicultural options provides the forest manager with flexibility in harvest scheduling, enables the regulation of the flow of forest products under different management scenarios, and is used to achieve and maintain target forest conditions.

(c) Forest estate computer modeling: Forest estate models are used to determine the management necessary to achieve economic, ecological, and social objectives within defined constraints, while simultaneously providing a sustainable yield of forest products and values. The forest estate model provides a schedule of harvest and other silvicultural treatments required to meet the forecasted sustainable wood supply capacity and achieve a desired future condition.

1.1   Growth and Yield model

A growth and yield model is an abstraction of natural stand dynamics and the effects of silvicultural intervention. A growth and yield model is used to predict the growth, yield (outputs), and future condition of forest stands under different types of silvicultural management. The various forest attributes calculated by the model are user-defined, and may include current and future growth, mortality, recruitment, commercial timber volume, habitat quality, structure, diversity, level of coarse woody debris, or other structural or compositional values.

Yield is the amount of a selected stand attribute present at a given point in time, such as the volume of commercial timber, average stand height, basal area, quadratic mean diameter (QMD), volume of coarse woody debris, habitat quality, stand structure, or forest development stage. Forest *growth* is the change in a selected stand attribute over a specified time period. Many economic, ecological and social interests are related to stand attributes. The various features of the yield tables are outlined in section 5 of this appendix.

The USDA Forest Service *Forest Vegetation Simulator* (FVS) was used to generate the necessary yield tables. FVS is a distant-independent, individual tree-level growth and yield model. This type of model is designed to process detailed individual tree data from inventory

plots to forecast how a given stand of trees will grow and change under different management prescriptions.

The condition of a given stand is modeled in successive 10 year growth cycles, using the tree list from the current inventory as a starting point. At the beginning of the growth cycle, the model selects each tree on the list for harvesting, natural mortality, or continued growth depending on the silvicultural prescription. New small trees occurring as a result of ingrowth or reproduction are added to the tree list. Trees are grown in height, diameter and crown size, to the end of the growth cycle. The model calculates the growth and volume for each tree and aggregates the data to provide area characteristics of growth and yield. The growth cycles were repeated for the 100 year planning horizon. The silvicultural prescriptions modeled are outlined in section 5 below.

Growth and yield models are used to model stand dynamics, attributes and values at the stand level. Forest level management objectives, policies, regulations and various management or market constraints are excluded. The dynamics of managing a forest estate for different objectives, often with multiple constraints, are addressed using models for harvest scheduling and wood supply forecasting.
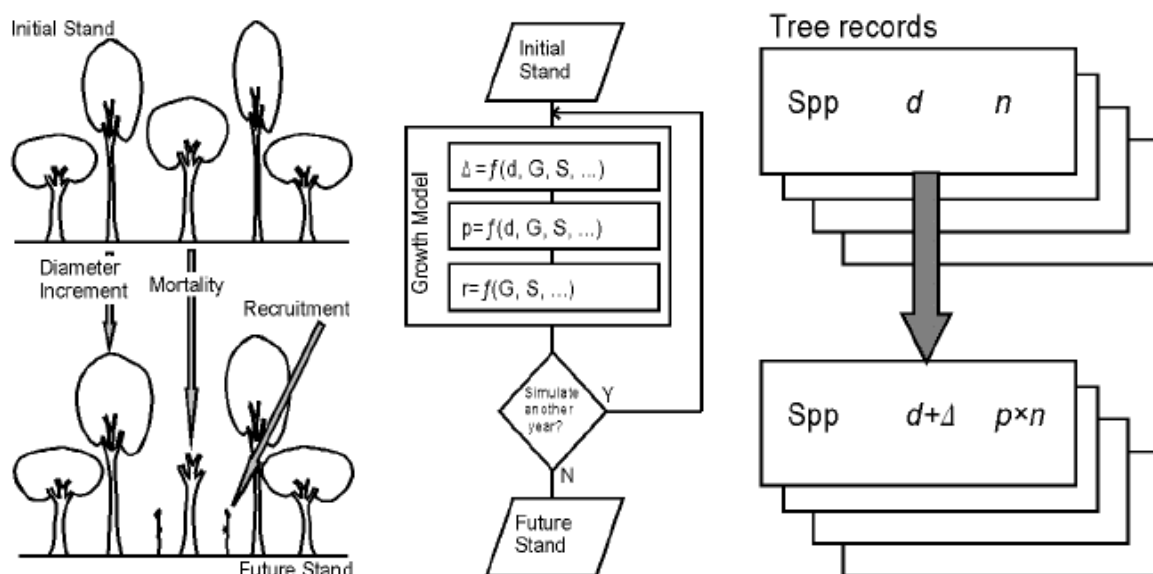
Figure C1. Tree records representing a forest stand. Growth is modeled by incrementing the diameter in each record (d + Δ). Mortality is accommodated by reducing expansion factors (p x n). Source: Vanclay (1994).

1.2   Forest Estate Model

The management of forest land for the simultaneous production of economic, social, and ecological values is complex. Computer models are used to represent current and future characteristics and their interactions across the landscape. Such models are used to evaluate management options and how changes in individual elements affect the landscape.

A forest estate model represents the essential parameters and condition of an existing forest resource and predicts future forest condition and outputs. The model enables the user to find

analytical solutions to forest land management problems that may include economic, ecological and social goals, policies, and regulatory constraints.

Spatial Woodstock, a commercial forest estate model developed by Remsoft Inc. Canada, was used to model the forested landscape in the South Puget Sound region. The model uses mathematical optimization techniques to provide solutions to land management scenarios.

Spatial Woodstock enables the user to build a long-term sustainable management model of wood supply, habitat, biodiversity, watershed management and other forest values. The model schedules the silvicultural operations and harvesting events required to achieve the wood supply forecast. Woodstock can be structured to model both physical (e.g., area, yield, habitat) and financial attributes, enables spatial mapping of forest parameters and activities, and can report changes to the forest condition and yield flows over time.

The forest estate model requires four categories of information as input:

(a)   Forest area classification: The forest area is classified according to site quality, forest cover (forest type composition, structure, condition), and silvicultural status.

(b)   A range of yield tables (forecast of forest values) for each unique combination of land productivity / forest area classifications is used to reflect the forest condition and outputs under different silvicultural regimes.

(c)   Management objectives: A standard objective is to maximize the forest estate net present value; other objectives can be expressed as constraints.

(d)   Constraints (temporal and pseudo-spatial) represent the array of economic, ecological and social objectives, expectations and restrictions required for effective forest land management. Constraints may be either area specific or timber production related:

Area specific constraints include:
- management practices and policies (permissible silviculture or restrictions) for different land classes (e.g., unstable slopes, visual corridor areas, deferred areas, riparian management)
- regulations guiding replanting, the retention of legacy trees, Habitat Conservation Plan targets, minimum canopy cover within watershed, maximum canopy opening size, green-up adjacency constraint, etc.
- special provisions, such as those outlined in *Washington Environmental Council et al, v. Sutherland et al, 2006* (hereafter, the "Settlement Agreement")

Timber production related constraints include:
- wood supply agreements (minimum volumes)
- flow constraints (regulating the level of change in production over time and within geographical areas or ownership classes)
- minimum revenue or net cashflow required
- existing planned harvest (2 – 3 year forward planning of harvest operations)
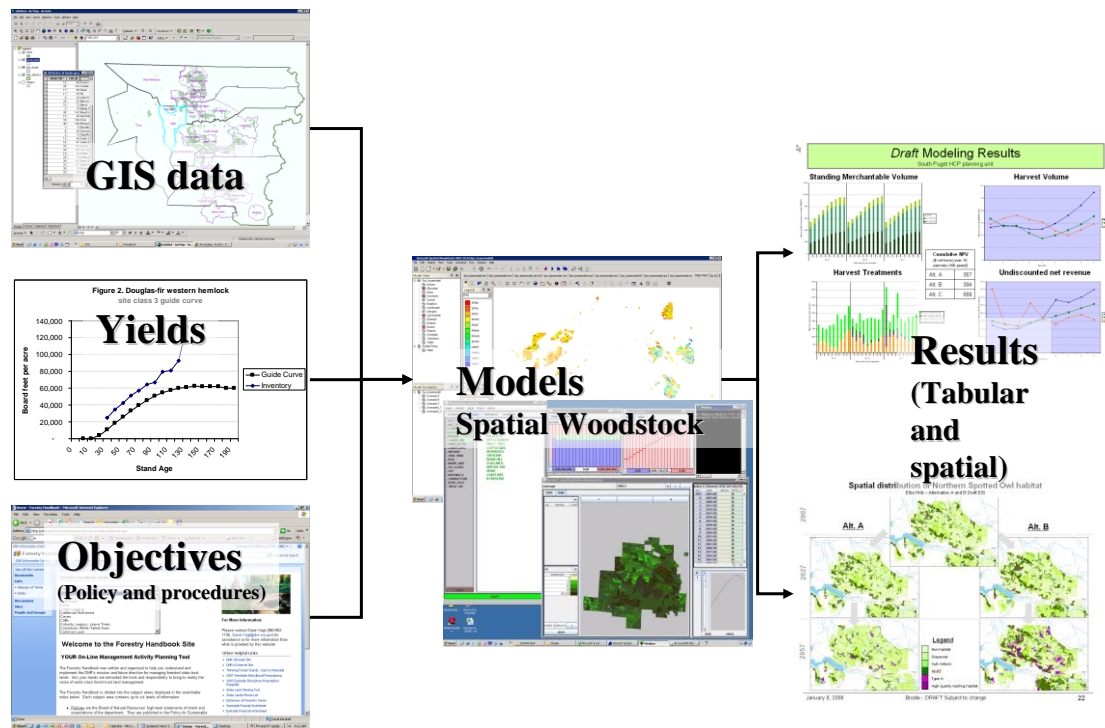
Figure C2. Schematic representation of forest estate modeling. Spatial data, including forest area classifications from a GIS are combined with Growth and Yield data and management objectives to produce a long-term sustainable management model of wood supply, habitat, biodiversity, watershed management and other forest values.

Spatial Woodstock uses a combination of linear and goal programming to solve land management problems. Conflicting constraints on land use may preclude a feasible solution. Goal programming within the model allows trade-offs to occur. Constraints are coded as either hard (those that cannot be violated) or soft (those that may be violated at a cost). All soft constraints incur an assigned penalty cost if violated. The penalty is deducted from the objective function. Since the model was structured to maximize the objective function, violation of soft constraints is minimized in achieving a solution.

2. LAND CLASSIFICATION

The classification system used in the model was constructed from an overlay of several GIS data layers for the South Puget HCP Planning Unit. The GIS data layers formed the basis for the creation of 10 *themes* for use with Spatial Woodstock, listed in Table C1 and described in greater detail in following sections of this document.

The intersected polygons, formed from the overlay of the multiple GIS data layers, were then grouped according to the unique combination of attributes to create modeling units. Approximately 250,000 modeling units were used, representing the combinations of various administrative, ecological, hydrologic, and forest attributes. Attributes included ownership, land class, watershed administrative unit (WAU), spotted owl management unit (SOMU), stand composition, condition, productivity, and silvicultural status.

Table C1. Spatial Woodstock themes

No.	Theme	Data Source
1	Surface and timber ownership groups	
2	Deferrals	
3	Watershed (WAU and SOMU)	
4	Land class	
5	Rain-on-snow sub-basins	
6	Forest type	FRIS
7	Site class	FRIS
8	Size class	FRIS
9	Stocking class	FRIS
10	Silvicultural status	P&T

FRIS: Forest Resource Inventory System
P&T: Planning and Tracking

2.1 Surface and Timber Ownership Groups

The surface and timber ownership theme includes three ownership categories: non-trust lands, federally granted trusts and purchased lands, and state forest board transfer lands. Each category is a grouping of several classes listed below.

Non-Trust Lands
NAP	Natural Area Preserves
NRCA	Natural Resource Conservation Area
WPCD	Water Protection Cooperative District
ADMIN-SITE	Administrative Site

Federally Granted Trusts and Purchased lands (FED-GRANT)
AGRIC-SCH	Agricultural School
CAPITOL-GRNT	Capitol Grant
CEP&RI	Charitable/Educational/Penal & Reformatory Institute
CEP&RI-TRANS	Charitable/Educational/Penal & Reformatory Institute / Transferred CMNTY-COLL – Community College
COM-SCHL/IND	Common School and Indemnity
ESCHEAT	Escheat
FOR-BD-PURCH	State Forest Board Purchase

NORMAL-SCH Normal School
SCIENTIC-SCH Scientific School
UNIV-ORIG University - Original
UNIV-TRANS University - Transferred

State Forest Board Transfer lands (SFB-TRNF) for each county
  FBT-KING
  FBT-KITSAP
  FBT-LEWIS
  FBT-MASON
  FBT-PIERCE
  FBT-SNOHOMISH
  FBT-THURSTON

Only Pierce and Kitsap counties are completely contained with the South Puget HCP Planning unit.

2.2 Deferrals

Forest land deferrals follow designations in the *Policy for Sustainable Forests*, the *Habitat Conservation Plan*, and the *Settlement Agreement*.

Long-term deferred areas include:
  Parks
  Gene pools
  NAPs and NRCAs
  Selected local operational constraints
  Marbled murrelet occupied sites, reclassified and non-occupied
  Buffer around location of NRF management nest core areas (2052)
  300 acre nest patch core areas (2052)

Short-term deferred areas include:
  Settlement Agreement owl areas and habitat classes
  Selected local operational constraints (varied)

Long-term means harvest deferrals beyond the first period, in this case 2017. Short-term means harvest deferrals that are released at the end of the first period (2017). The year in brackets means the year of release.

A six-digit alphanumeric code was used to identify and classify deferral areas, as described in Table C2 below.

Table C2. Six-digit alphanumeric code used to identify and classify deferral areas.

Posi	Type	Name	Description	Values
1-2	Num	Deferral years	2 digit numeric code representing the year area is released from deferral. Release begins on Jan 1 of the given year.	00 = no deferral 07 = 2007, stand is released 1/1/2007 14 = 2014, stand is released 1/1 2014 99 = permanent deferral
3	Char	Murrelet habitat	1 character code indicating whether deferral area is classified as marbled murrelet habitat	M = murrelet habitat N = non-habitat
4	Char	NSO habitat	1 character code indicating northern spotted owl habitat classification, per Forestry Handbook procedure PR 14-004-120 *Northern Spotted Owl Management (Westside)*. Codes were reclassified and regrouped for use within the model. See table C2 below.	A = type A high quality nesting habitat B = type B high quality nesting habitat S = sub-mature habitat Y = young forest marginal D = dispersal habitat X = next best stands N = non-habitat
5	Char	Old growth index	1 character classification of the potential for the presence of old growth forest conditions, per assessment of structural conditions as outlined in the Westside Old Growth Index	H = high potential for old growth (WOGHI[1] ≥ 60) M = moderate potential for old growth (50 ≤ WOGHI < 60) N = not old growth (WOGHI < 50) O = OESF old growth
6	Char	Thinning per concurrence letter	1 character code indicating deferral area includes timber sales eligible for thinning to RD 45 and 125 trees per acre as identified in the USFS / DNR concurrence letter (Berg 2005)	C = included in concurrence letter N = not included in concurrence letter

Existing NSO habitat management codes were reclassified and regrouped for use within the model, as described in Table C3 below.

Table C3. Crosswalk of northern spotted owl management to habitat coding

NSO-MGT-CD	Description	NSO-HAB
-1	Non-habitat (outside of NSO range)	N
A	High quality habitat	A
B	High quality habitat	B
D	Dispersal habitat	D
DS	Dispersal habitat (settlement)	D
DS	Next best (settlement)	X
N	Next best	X
N	Non-habitat, within NSO range	N
S	Sub-mature habitat	S
SS	Next best (settlement)	X
U	Next best	X
U	Unknown stands	U
Y	Young forest marginal habitat	Y
YS	Next best (settlement)	X

Old Growth Habitat Index (WOGHI) is a screening tool that uses data from DNR's Forest Resource Inventory System

Table C4. Northern spotted owl habitat definitions

ATTRIBUTES	HIGH QUALITY NESTING	TYPE "A" SPOTTED OWL	TYPE "B" SPOTTED OWL	MoRF	SUB-MATURE	YOUNG FOREST MARGINAL	DISPERSAL
LIVE TREES							
Species Requirement (West Side)	none	Multi-species (2nd Species: 20.0+% Trees/Ac)	Multi-species (2nd Species: 20.0+% Trees/Ac)	30.0+% Conifer, Trees/Ac	30.0+% Conifer, Trees/Ac	30.0+% Conifer, Trees/Ac	
Layers Requirement	None	2+	2+	none	none	none	none
Canopy Cover Requirement	none	none	none-	70+%	70+%	70+%	70+%
Canopy closure	70+%	70+%	70+%	none	none	none	
Deformity Requirement	Broken Tops: 21 in. DBH class,	Broken Tops: 21 in. DBH Class,	Broken Tops: 21 in. DBH Class				
LIVE TREES							
Min. Top Height (ft.) *(40 Largest Trees)*	none	None	none	85.0	85.0	85.0	85.0
Min. QMD (in.) *(100 Largest Trees)*	none	none	none	none	none	none	11.0
LIVE TREES (#1)							
Min. DBH Class	21	30	20				
Min. Stems/Ac	31.0+	15.0	75.0	115.0	115.0	115.0	100.0+
Max. Stems/Ac	none	75.0	100.0	280.0	280.0	280.0	none
LIVE TREES (#2)							
Min. DBH Class	31						
Min. Stems/Ac	15.0+	none	None	none	none	none	none
Max. Stems/Ac	none						
SNAGS							none
Min. DBH Class	21	30	20	15	20	20	
Min. Stems/Ac	12.0+	2.5+	1.0+	3.0+	3.0+	2.0+ (or down wood requirement)	
DOWN WOOD							none
Ground Covered	5.0+ %	5.0+ %	5.0+ %	5.0+ %	5.0+ %	5.0+ %	
Cu. Ft. / Ac	2400	2400	2400	2400	2400	4800 (or 2 snags per acre requirement)	

(1)   Minimum DBH Class for all live trees is 4 inches.
(2)   Minimum tree diameter for live trees and snags is the nominal class value less 0.5 inches (e.g. 4-inch class minimum tree size is 3.5 inches).
(3)   Deformity requirements are NOT applied at this time (i.e. 9/9/2005).
(4)   Down woody debris is an inferred parameter not directly found in Final Habitat Conservation Plan, Sept. 1997, Part IV, Habitat Definitions, p.11-19.
(5)   Shrub cover requirements for OESF are NOT applied at this time (i.e. 9/9/2005).
        Canopy cover and closure requirements are met if Curtis' relative density is greater than or equal to RD 48

Next best stands are the non-habitat stands within a given Spotted Owl Management Unit (SOMU), judged by a wildlife biologist as the soonest to reach the desired habitat threshold. Next best stands were only selected from SOMUs that are currently under the 50 percent target threshold level.

Unknown stands lack a sample inventory and therefore could not be screened for Northern Spotted Owl habitat. In the modeling process, all stands are assigned to various forest strata, containing a representation of all yield variables, including habitat. Overestimation of habitat in the some of the SOMU is a likely a result of this process of assigned stands to strata.

The following 68 deferral codes were used in the model:

00NDMC	00NNMC	00NYHC	00NAHN	00NBMN	00NBNN
00NDMN	00NDNC	00NDNN	00NNHN	00NNMN	00NNNC
00NNNN	00NSHN	00NSMN	00NSNC	00NSNN	00NUNC
00NUNN	00NXMN	00NXNC	00NXNN	00NYHN	00NYMN
00NYNC	00NYNN	10NDNC	10NDNN	10NNNC	10NNNN
10NUNC	10NUNN	10NXNC	10NXNN	14NNNN	15NNNN
15NUNN	17NNNN	22NNNN	47NNNN	47NSMN	47NUNN
47NXNN	47NNNC	47NSMC	47NXNC	99NSMC	99NSNC
99NXNC	99NUNC	99NAHN	99NBNN	99NDMN	99NDNC
99NDNN	99NNHN	99NNMN	99NNNC	99NNNN	99NSHN
99NSMN	99NSNN	99NUNN	99NXMN	99NXNN	99NYHN
99NYMN	99NYNN				

2.3   Watersheds (WAU and SOMU)

The following codes were used to identify the Watershed Administrative Unit (WAU) and Spotted Owl Management Unit (SOMU) for a given location.

As established by WAC 222-22-020, the state is divided into areas known as watershed administrative units (WAUs). WAU boundaries were defined by the DNR in cooperation with the departments of Ecology, Fish and Wildlife, affected Indian tribes, local governments, forest land owners, and the public. WAU's are the basic hydrologic units used for watershed analysis. WAU boundaries are mainly along drainage divides (ridges), with some along rivers and other DNR management boundaries. In the forested areas of the state, the WAUs range in size from 3,822 to 297,614 acres with a mean of 40,187 acres.

The following WAUs were included in the model. The code consists of a six-digit identifier and name.

100204-MIDDLE-WHITE   00205-GREENWATER   100302-LOWER-
WHITE
    100416-SOUTH-PRAIRIE   100418-CARBON   100519-ELECTRON
    110112-NF-MINERAL-CR   110202-TANWAX-CREEK   110203-OHOP-CREEK
    110215-POWELL-CREEK   110301-MUCK-CREEK   110316-YELM-CREEK
    110317-MCALLISTER   120101-CHAMBERS-CLOV   130104-MIDDLE-DESCHU
    130201-WOODLAND-CREE   130202-MCLANE-CREEK   130203-LOWER-DESCHUT
    140101-MASON   140102-KENNEDY-CREEK   140103-SQUAXIN-
ISLAN
    140104-HARSTINE-ISLA   150102-VASHON-ISLAND   150103-COLVOS-
PASSAG
    150106-KEY-PENINSULA   150107-S-SINCLAIR-IN   150108-CHICO-CREEK
    150109-DYES-INLET   150110-LIBERTY-MILLE   150201-GREAT-BEND
    150201-GREAT-BEND-Lk[2] 150202-W-KITSAP   150203-BANGOR-PORT-G
    150204-LYNCH-COVE   160106-LOWER-SKOKOMI   220106-MOX-CHEHALIS
    230403-SCATTER-CREEK   230404-LOWER-SKOOKUM   230522-PORTER-CREEK
    230601-WADDEL-CREEK   230602-BLACK-RIVER   260338-SILVER
    70408-RAGING-RIVER   70429-PATTERSON-CREE   80105-LOWER-CEDAR-RI
    80303-TIGER   80304-LAKE-SAMMAMISH   80402-SAMMAMISH-RIVE
    90103-HOWARD-HANSEN   90209-NEWAUKUM   90301-LOWER-GREEN-DU
    90410-S-ELLIOTT-BAY/

Within the model, active management within each WAU is conducted in a manner that
maintains a specified minimum level of mature forest cover.

The Spotted Owl Management Unit (SOMU) is a land classification used for the analysis of
habitat conditions and tracking of required amounts of suitable habitat for the Northern Spotted
Owl. SOMU boundaries were derived from watershed administrative units, and essentially
retain the 1997 WAU boundaries with minor changes. See *PR 14-004-120 Northern Spotted
Owl Management (Westside)* for additional information.

The following SOMU codes were included in the model:

    ASHFORD
    BIG-CATT
    BUSY-WILD
    GRASS-MOUNTAIN
    GREEN
    MINERAL-CREEK
    NORTH-FORK-GREEN
    NORTH-FORK-MINERAL
    PLEASANT-VALLEY-DISP
    PLEASANT-VALLEY-NRF
    REESE-CREEK

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[2] WAU *150201-GREAT-BEND-Lk* was used to represent the Lake Tahuya hydrologic maturity alternatives.

2.4 Land Classes

A land class code was used to classify management objectives, permitted silvicultural activities, and management constraints for a given area. The code consists of a composite of several fields, as described in table C5.

Table C5. Land class code.

Field	Description	Value(s)
1	Planning area	SPS — South Puget HCP Planning unit
2	Land class	GEM — General Ecological Management. Upland areas for which there are general (i.e., no species-specific) wildlife habitat requirements. All silviculture applies. Constraints on GEM lands are not spatially explicit, and include areas such as those used to meet leave tree and wildlife tree requirements for timber sales, or other other local, not spatially explicit operational constraints. GEM areas may have additional visual or slope stability constraints. RIP — Riparian areas, wetlands, and associated management zones as defined and managed according to Forestry handbook procedure PR 14-004-150 *Identifying and Protecting Riparian and Wetland Management Zones in the Westside HCP Planning Units, Excluding the OESF Planning Unit.* RIP areas are managed for ecosystem restoration, and are modeled such that only one future thinning is permitted. RIP areas may have additional visual or slope stability constraints. UPL — Upland areas with specific stand-level objectives. UPL areas were defined along WAU boundaries, and are used to model management constraints. For example, continuous maintenance of forest cover[3] is required for a percentage of the watershed. Upland areas include those managed to meet the habitat requirements of specific wildlife species, areas with spatially explicit local operational constraints, transition lands. UPL areas may have additional visual or slope stability constraints.
3	Additional constraints, represented as a suffix of the GEM, UPL, or RIP land classed.	S — Areas of potentially unstable slopes, with at least 20% of the area identified with the potential for shallow rapid landslides. V — visual management areas Either, neither, or both codes may be used. Silvicultural operations are more restricted in lands identified with the S or V suffix.

Other landscape-level management strategies, including those that apply to Northern Spotted Owl Nesting, Roosting & Foraging (NRF) and Dispersal Management areas, and rain-on-snow sub-basins, are represented in individual themes in the model. Local knowledge was collected and digitized during the planning process from DNR forest managers and local stakeholder groups. These data were incorporated into the GEMS, UPL, and visual management areas.

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[3] Relative density (RD) was used as a measure of forest cover. For thinning group 1, RD ≥ 48; for thinning group 2, RD ≥ 25.

The following land class codes were used in the model:

> SPS-GEM
> SPS-GEM-V
> SPS-GEM-S
> SPS-GEM-V-S
> SPS-RIP
> SPS-RIP-V
> SPS-RIP-S
> SPS-RIP-V-S
> SPS-UPL
> SPS-UPL-ALL   The upland class aggregate "UPL-ALL" was used to represent areas of potentially deep seated and shallow rapid unstable slopes, recreation areas, and local knowledge, including visual management areas.
>
> SPS-UPL-V
> SPS-UPL-S
> SPS-UPL-V-S

2.5   Rain-on-Snow Sub-Basins

The rain-on-snow zone is an area, generally defined as an elevation zone, where it is common for the snowpack to be partially or completely melted during rainstorms several times during the winter. Within the South Puget HCP Planning Unit, 50,043 acres of land are located within the rain-on-snow zone. Rain-on-snow sub-basins are identified in accordance with the Forestry Handbook procedure PR 14-004-060 *Assessing Hydrologic Maturity.* The requirements outlined in the procedure are designed to minimize adverse impacts caused by peak flows associated with rain-on-snow events to ecosystems that support salmonids. Hydrologic maturity is accomplished by maintaining an adequate amount of forest land within rain-on-snow zones in forests that are hydrologically mature with respect to rain-on-snow events.

A modeling target for hydrologic maturity was defined as having a relative density (RD) ≥ 25 over at least 66% of the total area within rain-on-snow critical sub-basins.

Development types containing basins within the rain-on-snow zone were assigned a unique number. Development types without basins in the rain-on-snow zone are assigned a code of "NOT-ROS".

The following rain-on-snow basin codes were used in the model:

08030306	09010301	09010304	09010305	09010306	09010308
09010401	09020203	11010801	11010803	11010901	11010903
11010905	11010906	11010907	11011201	11011202	11011203
11011204	11011205	11011206	11011207	11011304	11020402
11020403	11020405	23052203	NOT-ROS		

2.6　Forest Types

A four character forest type code was used to classify the primary and secondary overstory tree species groups found in a given area. The following twelve forest type codes were used in the model:

DFMA	Douglas-fir dominated, with hardwoods
DFRA	Douglas-fir dominated, with red alder
DFRC	Douglas-fir dominated, with western red cedar
DFWH	Douglas-fir dominated, with western hemlock
RADF	Red alder dominated, with Douglas-fir
RAMA	Red alder dominated, with other hardwoods
RAWH	Red alder dominated, with western hemlock
SFWH	Silver fir dominated, with western hemlock
WHDF	Western hemlock dominated, with Douglas-fir
WHRA	Western hemlock dominated, with red alder
WHRC	Western hemlock dominated, with western red cedar
WHSF	Western hemlock dominated, with silver fir

Each species group is a combination of several individual species. Twenty-six species were identified and assigned to eight species groups. The individual species and associated attributes are described in Table C8. Ninety-six primary and secondary species combinations were identified, which correspond to 12 primary and secondary species group (forest type) combinations. Table C9 describes the species combinations and the corresponding forest type.

2.7　Site Class

The land base was stratified into five site productivity classes, based on the 50 year site index (SI_{50}). The site index is the height of the dominant tree species (in feet) at a given location at age 50 years. Table C6 lists the site productivity classes and the corresponding range of site index values. The number of site classes was reduced from five to three within the model since site class 1 and site class 5 represented a small proportion of the total land base. Site class 1 was combined with site class 2, and site class 4 was combined with site class 5.

Table C6. Site class

Site Class	Site Index (SI_{50}) (feet)			
SIC1	137	≤	SI_{50}	
SIC2	119	≤	SI_{50}	< 137
SIC3	97	≤	SI_{50}	< 119
SIC4	76	≤	SI_{50}	< 97
SIC5	0	≤	SI_{50}	76

2.8　Size Class

The land base was stratified into five forest size classes based on quadratic mean diameter (QMD) for given stand. Only live trees with a dbh ≥ 3.5 inches (8.9 cm) were included in the calculation. The quadratic mean diameter is the square root of the mean square diameter for the stand (Eq. C1). Table C7 lists the size classes and the corresponding range of QMD values.

Table C7. Size class

Size Class	QMD (inches)			
SIZE1	0	≤	QMD	< 8
SIZE2	8	≤	QMD	< 14
SIZE3	14	≤	QMD	< 18
SIZE4	18	≤	QMD	< 24
SIZE5	24	≤	QMD	

Eq. C1.
$$QMD = \sqrt{\frac{\sum_{i=1}^{n} dbh_i^2}{n}}$$

Table C8. Individual species

Species Code	Common Name	Scientific Name	Species Group	Wood Type	Shade Tolerance	Acres	Hectares
AS	Aspen	*Populus tremuloides*	MA	Hardwood	Intolerant	129.0	52.2
BC	Black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	MA	Hardwood	Intolerant	5,452.3	2,206.5
CA	Cascara	*Frangula purshiana*	NC	Hardwood	Intolerant	2,976.0	1,204.3
DF	Douglas-fir	*Pseudotsuga menziesii*	DF	Softwood	Intolerant	141,784.8	57,378.3
ES	Engelmann spruce	*Picea engelmannii*	DF	Softwood	Intolerant	127.9	51.8
GF	Grand fir	*Abies grandis*	DF	Softwood	Intolerant	1,283.1	519.3
LP	Lodgepole pine	*Pinus contorta*	WP	Softwood	Intolerant	8,527.9	3,451.1
MA	Bigleaf maple	*Acer macrophyllum*	MA	Hardwood	Intolerant	15,235.3	6,165.5
MD	Pacific madrone	*Arbutus menziesii*	NC	Hardwood	Intolerant	1,244.5	503.6
MH	Mountain hemlock	*Tsuga mertensiana*	WH	Softwood	Tolerant	91.0	36.8
NC	Mixed non-commercial hardwoods		NC	Hardwood	Intolerant	8.5	3.4
NF	Noble fir	*Abies procera*	SF	Softwood	Tolerant	4,890.6	1,979.2
OA	Oregon ash	*Fraxinus latifolia*	MA	Hardwood	Intolerant	1,186.6	480.2
OO	Oregon oak	*Quercus garryana*	MA	Hardwood	Intolerant	18.0	7.3
PP	Ponderosa pine	*Pinus ponderosa*	WP	Softwood	Intolerant	5.5	2.2
PY	Pacific yew	*Taxus brevifolia*	NC	Softwood	Intolerant	118.6	48.0
RA	Red alder	*Alnus rubra*	RA	Hardwood	Intolerant	72,922.6	2,9510.7
RC	Western red cedar	*Thuja plicata*	RC	Softwood	Tolerant	30,911.7	12,509.5
SF	Pacific silver fir	*Abies amabilis*	SF	Softwood	Tolerant	16,760.7	6,782.8
SS	Sitka spruce	*Picea sitchensis*	DF	Softwood	Intolerant	113.2	45.8
TF	True fir	*Abies spp.*	SF	Softwood	Tolerant	2,198.5	889.7
VM	Vine maple	*Acer circinatum*	NC	Hardwood	Intolerant	156.8	63.5
WH	Western hemlock	*Tsuga heterophylla*	WH	Softwood	Tolerant	98,909.6	40,027.3
WO	Willow	*Salix* spp.	NC	Hardwood	Intolerant	1,610.3	651.7
WP	White pine	*Pinus monticola*	WP	Softwood	Intolerant	10,545.9	4,267.8
YC	Alaska yellow cedar	*Cupressus nootkatensis*	RC	Softwood	Tolerant	37.6	15.2

Table C9. Species group to forest type

Species Group Code	Species Group Name	Forest Type Code	Forest Type Name	Shade Tolerance
ASDF	Aspen / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
BCDF	Black cottonwood / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
BCRA	Black cottonwood / Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
CADF	Cascara / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DF	Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFAS	Douglas-fir / Aspen	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFBC	Douglas-fir / Black cottonwood	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFCA	Douglas-fir / Cascara	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFGF	Douglas-fir / Grand fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFLP	Douglas-fir / Lodgepole pine	DFWH	Douglas-fir / Western hemlock	Intolerant
DFMA	Douglas-fir / Bigleaf maple	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFMD	Douglas-fir / Pacific madrone	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFNC	Douglas-fir / Mix-Noncommercial hardwoods	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFNF	Douglas-fir / Noble fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFOA	Douglas-fir / Oregon ash	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFPY	Douglas-fir / Pacific yew	DFWH	Douglas-fir / Western hemlock	Intolerant
DFRA	Douglas-fir / Red alder	DFRA	Douglas-fir / Red alder	Intolerant
DFRC	Douglas-fir / Western red cedar	DFRC	Douglas-fir / Western red cedar	Intolerant
DFSF	Douglas-fir / Pacific silver fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFTF	Douglas-fir / True fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFVM	Douglas-fir / Vine maple	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFWH	Douglas-fir / Western hemlock	DFWH	Douglas-fir / Western hemlock	Intolerant
DFWO	Douglas-fir / Willow	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFWP	Douglas-fir / White pine	DFWH	Douglas-fir / Western hemlock	Intolerant
GF	Grand fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
GFDF	Grand fir / Douglas-fir	DFSF	Douglas-fir / Pacific silver fir	Intolerant
LP	Lodgepole pine	DFWH	Douglas-fir / Western hemlock	Intolerant
LPDF	Lodgepole pine / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
MA	Bigleaf maple	RAMA	Red alder / Bigleaf maple	Intolerant
MADF	Bigleaf maple / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
MARA	Bigleaf maple / Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
MARC	Bigleaf maple / Western red cedar	DFMA	Douglas-fir / Bigleaf maple	Intolerant
MAWH	Bigleaf maple / Western hemlock	WHRA	Western hemlock / Red alder	Tolerant
MDDF	Pacific madrone / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
MDMA	Pacific madrone / Bigleaf maple	RAMA	Red alder / Bigleaf maple	Intolerant
NC	Mix-Noncommercial hardwoods	RAMA	Red alder / Bigleaf maple	Intolerant
NCDF	Mix-Noncommercial hardwoods / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant

Species Group Code	Species Group Name	Forest Type Code	Forest Type Name	Shade Tolerance
NCMA	Mix-Noncommercial hardwoods / Bigleaf maple	RAMA	Red alder / Bigleaf maple	Intolerant
NCRA	Mix-Noncommercial hardwoods / Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
NF	Noble fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
NFDF	Noble fir / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
NFMH	Noble fir / Mountain hemlock	SFWH	Pacific silver fir / Western hemlock	Tolerant
NFOA	Noble fir / Oregon ash	WHRA	Western hemlock / Red alder	Tolerant
NFRA	Noble fir / Red alder	WHRA	Western hemlock / Red alder	Tolerant
NFSF	Noble fir / Pacific silver fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
NFWH	Noble fir / Western hemlock	SFWH	Pacific silver fir / Western hemlock	Tolerant
OODF	Oregon oak / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
PPDF	Ponderosa pine / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
RA	Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
RABC	Red alder / Black cottonwood	RAMA	Red alder / Bigleaf maple	Intolerant
RADF	Red alder / Douglas-fir	RADF	Red alder / Douglas-fir	Intolerant
RAES	Red alder / Engelmann spruce	WHRA	Western hemlock / Red alder	Tolerant
RAGF	Red alder / Grand fir	WHRA	Western hemlock / Red alder	Tolerant
RAMA	Red alder / Bigleaf maple	RAMA	Red alder / Bigleaf maple	Intolerant
RAMD	Red alder / Pacific madrone	RAMA	Red alder / Bigleaf maple	Intolerant
RANC	Red alder / Mix-Noncommercial hardwoods	RAMA	Red alder / Bigleaf maple	Intolerant
RANF	Red alder / Noble fir	WHRA	Western hemlock / Red alder	Tolerant
RAOA	Red alder / Oregon ash	RAMA	Red alder / Bigleaf maple	Intolerant
RARC	Red alder / Western red cedar	RADF	Red alder / Douglas-fir	Intolerant
RASF	Red alder / Pacific silver fir	RAWH	Red alder / Western hemlock	Intolerant
RAWH	Red alder / Western hemlock	RAWH	Red alder / Western hemlock	Intolerant
RAWO	Red alder / Willow	RAMA	Red alder / Bigleaf maple	Intolerant
RC	Western red cedar	DFRC	Douglas-fir / Western red cedar	Intolerant
RCDF	Western red cedar / Douglas-fir	DFRC	Douglas-fir / Western red cedar	Intolerant
RCMA	Western red cedar / Bigleaf maple	RADF	Red alder / Douglas-fir	Intolerant
RCRA	Western red cedar / Red alder	DFRA	Douglas-fir / Red alder	Intolerant
RCWH	Western red cedar / Western hemlock	WHRC	Western hemlock / Western red cedar	Tolerant
SF	Pacific silver fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
SFDF	Pacific silver fir / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
SFMA	Pacific silver fir / Bigleaf maple	WHRA	Western hemlock / Red alder	Tolerant
SFNF	Pacific silver fir / Noble fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
SFOA	Pacific silver fir / Oregon ash	WHRA	Western hemlock / Red alder	Tolerant
SFRA	Pacific silver fir / Red alder	WHRA	Western hemlock / Red alder	Tolerant
SFRC	Pacific silver fir / Western red cedar	WHRC	Western hemlock / Western red cedar	Tolerant
SFWH	Pacific silver fir / Western hemlock	SFWH	Pacific silver fir / Western hemlock	Tolerant

Species Group Code	Species Group Name	Forest Type Code	Forest Type Name	Shade Tolerance
SFYC	Pacific silver fir / Alaska yellow cedar	WHSF	Western hemlock / Pacific silver fir	Tolerant
TF	True fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
TFDF	True fir / Douglas-fir	DFSF	Douglas-fir / Pacific silver fir	Intolerant
TFNC	True fir / Mix-Noncommercial hardwoods	SFWH	Pacific silver fir / Western hemlock	Tolerant
TFWH	True fir / Western hemlock	SFWH	Pacific silver fir / Western hemlock	Tolerant
WH	Western hemlock	WHSF	Western hemlock / Pacific silver fir	Tolerant
WHBC	Western hemlock / Black cottonwood	WHRA	Western hemlock / Red alder	Tolerant
WHDF	Western hemlock / Douglas-fir	WHDF	Western hemlock / Douglas-fir	Tolerant
WHMA	Western hemlock / Bigleaf maple	WHRA	Western hemlock / Red alder	Tolerant
WHNC	Western hemlock / Mix-Noncommercial hardwoods	WHRA	Western hemlock / Red alder	Tolerant
WHNF	Western hemlock / Noble fir	WHSF	Western hemlock / Pacific silver fir	Tolerant
WHOA	Western hemlock / Oregon ash	WHRA	Western hemlock / Red alder	Tolerant
WHPY	Western hemlock / Pacific yew	WHSF	Western hemlock / Pacific silver fir	Tolerant
WHRA	Western hemlock / Red alder	WHRA	Western hemlock / Red alder	Tolerant
WHRC	Western hemlock / Western red cedar	WHRC	Western hemlock / Western red cedar	Tolerant
WHSF	Western hemlock / Pacific silver fir	WHSF	Western hemlock / Pacific silver fir	Tolerant
WHWP	Western hemlock / White pine	WHDF	Western hemlock / Douglas-fir	Tolerant
WO	Willow	RAMA	Red alder / Bigleaf maple	Intolerant
WORA	Willow / Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
WPDF	White pine / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
WPWH	White pine / Western hemlock	WHDF	Western hemlock / Douglas-fir	Tolerant

2.9   Stocking Class

The land base was stratified into four stocking classes using Curtis relative density (RD). Relative density is the basal area of a stand divided by the square root of the quadratic mean diameter of the stand (Eq C2). Only live trees with a dbh ≥ 3.5 inches (8.9 cm) were included in the calculation. Table C10 lists the stocking classes and the corresponding range of RD values.

Eq. C2. $$RD = \frac{BA}{\sqrt{QMD}}$$

Table C10. Stocking class

Stocking Class Name	Stocking Class Code	RD (shade tolerant)	RD (shade intolerant)
Extremely over-stocked	EXSTK	100 ≥ RD	90 ≥ RD
Grossly over-stocked	GOSTK	75 ≥ RD < 100	70 ≥ RD < 90
Mortality induced stocking	MISTK	55 ≥ RD < 75	45 ≥ RD < 70
Optimal stocking	OPSTK	0 ≥ RD < 55	0 ≥ RD < 45

2.10   Silvicultural Status

The silvicultural status describes the current forest condition of a given stand as a result of its management history. The code consists of a combination of thinning and regeneration harvest designations plus the stand age at the time of the operation.

Thinning designation:

UT   unthinned
CT   commercial thin, including thin from below
MT   thinning treatment for NSO Movement, Roosting & Foraging (MoRF) and sub-mature habitat
AT   thinning treatment for Type A NSO habitat creation and older forests
PCT   pre-commercial thin

Regeneration harvest designation:

R0   regeneration harvest with 0 legacy trees per acre
R1   regeneration harvest with 10 legacy trees per acre
R2   regeneration harvest with 20 legacy trees per acre

Stand age at the time of the operation is represented by a two-digit code for the decadal age class

01 = 10 year age class
02 = 20 year age class, etc

Combinations of the above designations are used to represent stand management history. For example:

1AT03   First Type A thinning in a previously unthinned stand. Thinning operation completed when the stand was in the 30 year age class.

"1"   represents the first thinning in the planning period for the stand
"AT"   indicates Type A thinning
"03"   indicates the stand was in the 30 year age class

Table C11. Silvicultural status based on 2007 forest condition

Stand Management History	Silvicultural Status
First commercial thinning in previously unthinned stands	1CT00, 1CT01, 1CT02, 1CT03, 1CT04, 1CT05, 1CT06, 1CT07, 1CT08, 1CT09, 1CT10, 1CT11, 1CT12, 1CT13, 1CT14, 1CT15, 1CT16, 1CT17, 1CT18, 1CT19, 1CT20, 1CT21, 1CT22, 1CT23, 1CT24, 1CT25, 1CT26, 1CT27, 1CT28, 1CT29, 1CT30, 1CT31
First MoRF and sub-mature NSO habitat thinning in previously unthinned stands	1MT00, 1MT01, 1MT02, 1MT03, 1MT04, 1MT05, 1MT06, 1MT07, 1MT08, 1MT09, 1MT10, 1MT11, 1MT12, 1MT13, 1MT14, 1MT15, 1MT16, 1MT17, 1MT18, 1MT19, 1MT20, 1MT21, 1MT22, 1MT23, 1MT24, 1MT25, 1MT26, 1MT27, 1MT28, 1MT29, 1MT30, 1MT31
First Type A NSO habitat thinning	1AT00, 1AT01, 1AT02, 1AT03, 1AT04, 1AT05, 1AT06, 1AT07, 1AT08, 1AT09, 1AT10, 1AT11, 1AT12, 1AT13, 1AT14, 1AT15, 1AT16, 1AT17, 1AT18, 1AT19, 1AT20, 1AT21, 1AT22, 1AT23, 1AT24, 1AT25, 1AT26, 1AT27, 1AT28, 1AT29, 1AT30, 1AT31
First commercial thinning in regenerated stands with no legacy trees	R0-1CT03, R0-1CT04, R0-1CT05, R0-1CT06, R0-1CT07, R0-1CT08, R0-1CT09, R0-1CT10
First MoRF and sub-mature NSO habitat thinning in regenerated stands with no legacy trees	R0-1MT03, R0-1MT04, R0-1MT05, R0-1MT06, R0-1MT07, R0-1MT08, R0-1MT09, R0-1MT10
First Type A NSO habitat thinning in regenerated stands with no legacy trees	R0-1AT03, R0-1AT04, R0-1AT05, R0-1AT06, R0-1AT07, R0-1AT08, R0-1AT09, R0-1AT10
Second commercial thinning in regenerated stands without legacy trees	R0-1CT03-2CT06, R0-1CT03-2CT07, R0-1CT03-2CT08, R0-1CT03-2CT09, R0-1CT04-2CT07, R0-1CT04-2CT08, R0-1CT04-2CT09, R0-1CT04-2CT10, R0-1CT05-2CT08, R0-1CT05-2CT09, R0-1CT05-2CT10, R0-1CT06-2CT09, R0-1CT06-2CT10, R0-1CT07-2CT09, R0-1CT07-2CT10, R0-1CT08-2CT09, R0-1CT08-2CT10, R0-1CT09-2CT09, R0-1CT09-2CT10, R0-1CT10-2CT10
First commercial thinning in regenerated stands with 10 legacy trees per acre	R1-1CT03, R1-1CT04, R1-1CT05, R1-1CT06, R1-1CT07, R1-1CT08, R1-1CT09, R1-1CT10
First MoRF and sub-mature NSO habitat thinning in regenerated stands with 10 legacy trees per acre	R1-1MT03, R1-1MT04, R1-1MT05, R1-1MT06, R1-1MT07, R1-1MT08, R1-1MT09, R1-1MT10
First Type A NSO habitat thinning in regenerated stands with 10 legacy trees per acre	R1-1AT03, R1-1AT04, R1-1AT05, R1-1AT06, R1-1AT07, R1-1AT08, R1-1AT09, R1-1AT10
Second commercial thinning in regenerated stands with 10 legacy trees per acre	R1-1CT03-2CT06, R1-1CT03-2CT07, R1-1CT03-2CT08, R1-1CT03-2CT09, R1-1CT04-2CT07, R1-1CT04-2CT08, R1-1CT04-2CT09, R1-1CT04-2CT10, R1-1CT05-2CT08, R1-1CT05-2CT09, R1-1CT05-2CT10, R1-1CT06-2CT09, R1-1CT06-2CT10, R1-1CT07-2CT09, R1-1CT07-2CT10, R1-1CT08-2CT09, R1-1CT08-2CT10, R1-1CT09-2CT09, R1-1CT09-2CT10, R1-1CT10-2CT10
First commercial thinning in regenerated stands with 20 legacy trees per acre	R2-1CT03, R2-1CT04, R2-1CT05, R2-1CT06, R2-1CT07, R2-1CT08, R2-1CT09, R2-1CT10
First MoRF and sub-mature NSO habitat thinning in regenerated stands with 20 legacy trees per acre	R2-1MT03, R2-1MT04, R2-1MT05, R2-1MT06, R2-1MT07, R2-1MT08, R2-1MT09, R2-1MT10

Stand Management History	Silvicultural Status
First Type A NSO habitat thinning in regenerated stands with 20 legacy trees per acre	R2-1AT03, R2-1AT04, R2-1AT05, R2-1AT06, R2-1AT07, R2-1AT08, R2-1AT09, R2-1AT10
Second commercial thinning in regenerated stands with 20 legacy trees per acre	R2-1CT03-2CT06, R2-1CT03-2CT07, R2-1CT03-2CT08, R2-1CT03-2CT09, R2-1CT04-2CT07, R2-1CT04-2CT08, R2-1CT04-2CT09, R2-1CT04-2CT10, R2-1CT05-2CT08, R2-1CT05-2CT09, R2-1CT05-2CT10, R2-1CT06-2CT09, R2-1CT06-2CT10, R2-1CT07-2CT09, R2-1CT07-2CT10, R2-1CT08-2CT09, R2-1CT08-2CT10, R2-1CT09-2CT09, R2-1CT09-2CT10, R2-1CT10-2CT10

3. FOREST INVENTORY STRATIFICATION

Combinations of the above described forest inventory parameters (Forest Type, Site Class, Stocking Class, and Size Class) were used to stratify the planning unit. Since representative data (tree lists) were only available for stands sampled as part of the DNR inventory process; only sampled stands were used to generate yield tables in the Forest Vegetation Simulator (FVS). Table C12 lists the amount of the planning unit in each inventory type.

Table C12. Inventory type within the South Puget HCP Planning Unit

Resource Inventory Unit (RIU) type	Number of RIUs	Acres	Hectares	Percent of area
Legacy inventory (L)	601	29,253	11,838	20%
Sampled (P)	2,232	113,917	46,001	79%
Newly regenerated (R)	24	1,355	548	1%
Grand Total	2,857	144,525	58,487	100%

The stratification resulted in 303 strata out of a possible 780. In addition to the existing strata, three additional strata were added to represent newly regenerated stands and inventory stands, making a total of 306 strata. Table C13 presents basic inventory statistics for the top 42 strata representing 70 percent of the land base.

Table C13. Forest Stratification for the South Puget HCP Planning Unit: top 42 strata, ranked by area, representing 70% of the forested land base.

Strata	Number of Inventory units (RIUs)	Sum of ACRES	Average of SI	StdDev of SI	Average of BA3D5	StdDev of BA3D5	Average of TOPHT	StdDev of TOPHT	Average of QMD3D5	StdDev of QMD3D5	Average of TPA3D5	StdDev of TPA3D5	Average of RD3D5	StdDev of RD3D5	Average of BFMV	StdDev of BFMV	Average of Age	StdDev of Age	Max of Age	Min of Age	Strata area percent of Total	Cumulative Percent
DFWH_SIC3_GOSTK_Size2	208	12,093	106	7	259	21	115	12	11.6	1.1	361	59	76	5	34	5	45	25	112	1	8.4%	8%
DFWH_SIC3_MISTK_Size2	288	10,872	105	5	198	23	108	12	11.6	1.1	276	48	58	6	26	5	33	26	117	1	7.5%	16%
DFWH_SIC2_MISTK_Size3	176	7,202	125	6	255	17	135	12	15.7	1.1	192	25	64	4	40	4	38	27	111	1	5.0%	21%
DFWH_SIC4_MISTK_Size2	127	6,147	87	7	200	23	100	14	11.1	1.2	305	61	60	6	25	5	49	29	137	1	4.3%	25%
DFRA_SIC2_MISTK_Size3	134	4,482	126	5	243	21	134	12	15.9	1.1	178	26	61	5	38	4	43	30	108	1	3.1%	28%
DFRA_SIC3_MISTK_Size2	106	4,202	108	6	199	33	109	18	11.9	1.6	263	54	58	8	26	7	42	27	86	1	2.9%	31%
DFWH_SIC4_GOSTK_Size2	82	3,902	87	7	249	22	108	12	10.7	1.3	413	89	76	5	31	6	56	32	132	1	2.7%	34%
DFWH_SIC3_MISTK_Size3	105	3,866	110	5	239	30	126	11	15.3	0.7	189	27	61	8	36	6	40	34	223	1	2.7%	37%
DFWH_SIC2_GOSTK_Size2	67	3,197	125	5	272	21	126	20	12.4	1.0	329	44	77	5	39	6	46	27	83	1	2.2%	39%
DFRA_SIC3_MISTK_Size3	82	2,940	110	6	243	26	127	17	15.7	0.9	181	25	61	6	37	7	55	30	114	1	2.0%	41%
DFWH_SIC2_GOSTK_Size3	73	2,903	127	6	298	21	142	15	15.4	1.1	233	33	76	5	48	6	51	32	122	1	2.0%	43%
DFWH_SIC2_MISTK_Size2	45	2,220	124	4	219	22	117	22	12.2	1.2	276	52	63	6	31	6	46	30	140	2	1.5%	44%
DFMA_SIC2_MISTK_Size3	56	1,934	126	4	243	25	137	11	16.2	1.1	171	27	60	6	39	4	45	40	215	1	1.3%	46%
DFWH_SIC3_OPSTK_Size1	57	1,930	103	3	64	24	52	12	5.7	1.0	365	127	27	9	2	3	35	18	118	21	1.3%	47%
WHDF_SIC3_GOSTK_Size2	34	1,802	106	6	277	20	111	9	11.4	1.2	407	97	82	7	36	4	54	15	77	13	1.2%	48%
DFWH_SIC4_OPSTK_Size2	42	1,770	82	11	113	29	76	16	10.3	1.9	206	70	35	8	11	4	50	13	100	34	1.2%	49%
WHDF_SIC4_GOSTK_Size2	49	1,708	79	11	289	23	107	12	11.3	1.4	433	116	86	8	35	7	75	26	122	5	1.2%	51%
DFWH_SIC3_GOSTK_Size3	45	1,678	110	4	284	21	129	15	15.1	1.2	231	23	73	4	44	6	69	39	145	7	1.2%	52%
WHDF_SIC4_MISTK_Size2	26	1,500	83	9	223	21	92	22	11.5	1.3	317	73	66	6	26	7	50	23	125	16	1.0%	53%
DFWH_SIC4_OPSTK_Size1	50	1,423	80	15	59	27	44	12	5.7	1.0	332	131	24	10	2	2	41	29	131	19	1.0%	54%
SFWH_SIC4_MISTK_Size2	25	1,413	79	12	213	13	92	7	10.7	0.5	345	33	65	3	27	4	27	18	85	12	1.0%	55%
DFRA_SIC3_GOSTK_Size2	38	1,340	110	5	267	17	117	16	12.1	1.1	343	61	77	5	36	5	44	28	87	1	0.9%	56%
DFWH_SIC2_MISTK_Size4	26	1,261	129	6	257	19	149	12	19.5	1.3	126	19	58	5	45	5	65	22	86	5	0.9%	57%

Strata	Number of Inventory units (RIUs)	Sum of ACRES	Average of SI	StdDev of SI	Average of BA3D5	StdDev of BA3D5	Average of TOPHT	StdDev of TOPHT	Average of QMD3D5	StdDev of QMD3D5	Average of TPA3D5	StdDev of TPA3D5	Average of RD3D5	StdDev of RD3D5	Average of BFMV	StdDev of BFMV	Average of Age	StdDev of Age	Max of Age	Min of Age	Strata area percent of Total	Cumulative Percent
WHSF_SIC4_GOSTK_Size2	30	1,163	83	13	295	31	98	16	11.0	1.6	470	116	89	6	34	10	56	22	120	2	0.8%	57%
DFMA_SIC3_MISTK_Size3	31	1,161	110	6	231	24	129	14	16.0	1.1	167	23	58	5	36	5	51	38	156	2	0.8%	58%
DFRA_SIC2_GOSTK_Size2	36	1,158	126	6	272	18	125	18	12.8	1.1	312	54	76	4	38	5	38	28	93	1	0.8%	59%
WHDF_SIC3_MISTK_Size3	23	1,149	107	7	270	23	126	16	15.7	1.3	204	28	68	5	41	6	75	30	166	2	0.8%	60%
DFWH_SIC4_EXSTK_Size2	19	1,145	82	11	321	31	111	20	10.2	1.7	597	163	101	9	38	10	78	22	130	47	0.8%	61%
DFMA_SIC3_MISTK_Size2	37	1,144	110	5	210	28	115	17	12.1	1.4	267	51	60	7	28	7	29	29	85	1	0.8%	61%
WHDF_SIC4_OPSTK_Size2	16	1,119	83	9	145	27	79	13	10.8	1.5	235	72	44	8	15	4	45	16	74	1	0.8%	62%
DFRA_SIC2_MISTK_Size2	30	1,108	127	6	221	23	118	19	12.1	1.3	283	52	64	5	30	5	40	28	76	1	0.8%	63%
DFRA_SIC2_MISTK_Size4	45	1,096	129	5	256	24	147	12	19.2	1.2	129	20	58	6	43	5	50	32	88	2	0.8%	64%
SFWH_SIC4_OPSTK_Size1	32	1,056	77	11	53	34	36	9	5.1	0.7	353	193	23	14	1	1	31	8	48	21	0.7%	64%
RADF_SIC2_MISTK_Size3	32	1,013	130	4	240	21	121	11	16.2	1.1	171	26	60	5	36	4	61	22	91	1	0.7%	65%
WHDF_SIC2_GOSTK_Size2	16	966	127	9	281	15	120	11	11.4	1.1	411	99	84	7	38	3	57	9	72	44	0.7%	66%
DFRC_SIC2_MISTK_Size3	22	928	124	5	249	16	136	12	16.1	1.0	177	26	62	5	40	4	57	47	215	6	0.6%	66%
DFRA_SIC3_OPSTK_Size2	17	927	106	6	121	26	79	15	10.2	2.0	223	60	38	6	13	4	36	14	79	6	0.6%	67%
WHSF_SIC3_GOSTK_Size2	18	926	102	6	297	32	103	13	11.3	1.6	451	132	89	8	36	8	57	15	91	20	0.6%	68%
DFRA_SIC3_OPSTK_Size1	27	898	105	5	73	30	57	10	6.3	1.0	341	144	29	12	3	2	33	13	67	21	0.6%	68%
DFWH_SIC4_MISTK_Size3	28	891	89	7	234	31	122	10	15.1	0.7	189	27	60	8	35	6	46	32	120	1	0.6%	69%
WHDF_SIC3_MISTK_Size2	15	850	104	5	229	33	107	16	12.1	1.2	290	52	66	8	30	7	48	19	77	1	0.6%	70%
DFRA_SIC2_GOSTK_Size3	36	809	128	7	296	18	143	14	15.6	1.1	226	29	75	4	48	5	52	33	97	1	0.6%	70%

4. SILVICULTURE

4.1 Silvicultural Treatments and Regimes

The silvicultural treatment(s) applied to the forest resource depend on management objectives, regulations, policies and suitability of the forest types and land class. Considerations include the HCP regulations, Settlement Agreement status, habitat designation, visual corridor, upland stability characteristics, rain on snow targets (hydrological maturity), and economic factors. Permissible, restricted and modified silvicultual practices are outlined in the sections that follow.

In upland zones (GEM and UPL), forests are treated as even-aged stands unless variable retention harvest are implemented for habitat creation, or cover is maintained for visual or slope stability reasons. Riparian areas are only thinned once; these areas are to be restored to natural ecosystems without active forest management.

The general sequence of treatments that are applied in creating and maintaining even-aged stands are as follows:

Treatment options include:

- No thinning treatments: stands remain unthinned during simulation (UT).

- Regeneration harvest retaining nil, 10, or 20 trees per acre, followed by planting and natural regeneration.

    R0:   Regeneration harvest without residual trees during simulation runs
    R1:   Regeneration harvest with 10 residual trees during simulation runs
    R2:   Regeneration harvest with 20 residual trees during simulation runs

- Thinning: light (retaining 70% RD) and heavy (retaining 50% RD):

    CT: Commercial thinning
    MT: light intensity variable density thinning to create Northern Spotted Owl Movement, roosting, and forging (MoRF) habitat
    AT: Heavy intensity variable density thinning to create Northern Spotted Owl Type A habitat

- Planting Douglas-fir at 250 trees per acre and Red Cedar at 50 trees per acre with a 90% survival rate for all regeneration harvest treatments.

- Natural regeneration occurs regardless of silvicultural treatment. Naturally regenerate Western Hemlock at 550 trees per acre for West Cascades (WC) FVS variant or 150 trees per acre for Pacific Northwest (PN) variant with a 60% survival rate for all regeneration harvest treatment.

4.2   Modeled Silvicultural Regimes

The yield tables used in Woodstock are based on the predominant silvicultural regimes that DNR uses or plans to use for stand-level forest management. Regimes have been modeled both for existing stands over 30 years of age, and those which are less than 30 years or will be regenerated in the future.

A range of permitted potential silvicultural pathways is modeled for each stand. The options provide the flexibility to achieve the forest estate level objectives that address a multitude of competing and often conflicting land use targets (e.g., trade-offs between timber harvest and habitat development or riparian restoration).

A range of silvicultural pathways, coupled with flexible rotation lengths, is necessary to regulate the flow of timber in a heterogeneous forested land base, variable with respect to stand development stage, species composition, structure, geographic distribution, and growth rate.

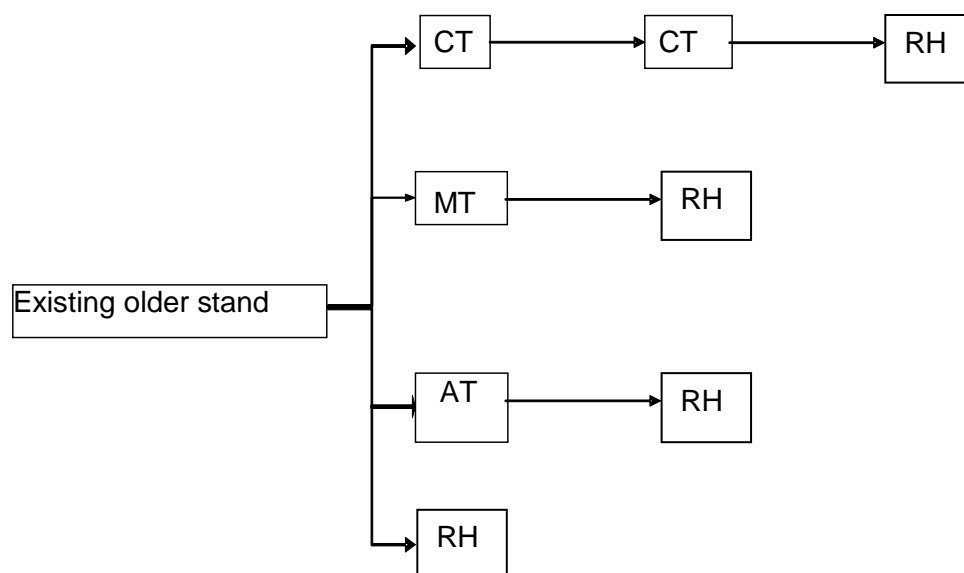The range of possible regime pathways is illustrated in the following diagrams:

Figure C3. Silvicultural pathways for existing stands older than 30 years.
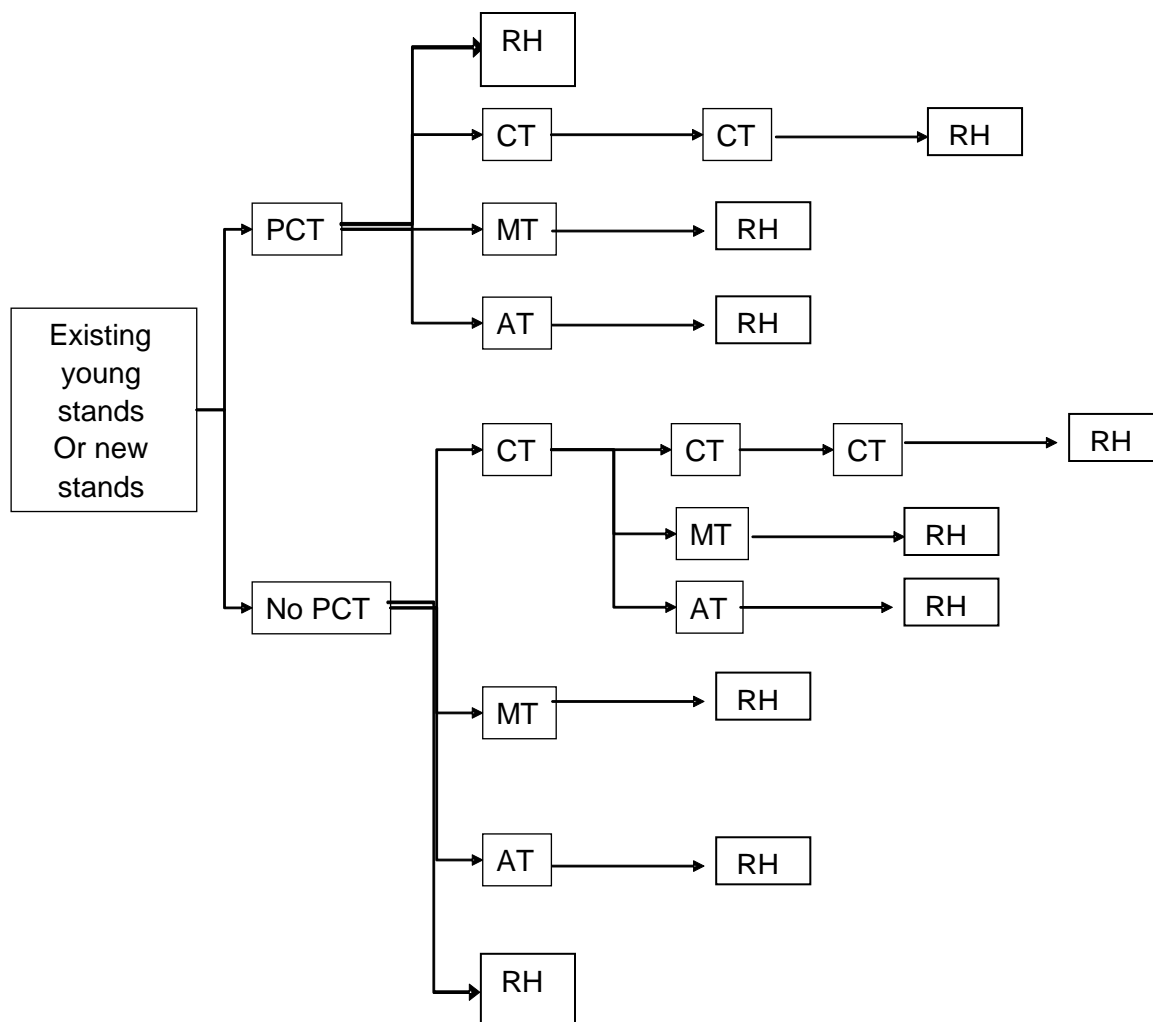
Figure C4. Silvicultural pathways for newly regenerated stands and stands less than 30 years of age.

Thinning:

CT   Commercial thinning
MT   Light variable density thinning with an objective of Movement, roosting, and foraging (MoRF) and Sub-mature habitat
AT   Heavy variable density thinning with an objective of Northern spotted owl (NSO) Type A habitat thinning

Regeneration harvest:

RH   Regeneration harvest. May include a final harvest without any residual legacy trees or with retention of 10 and 20 largest legacy trees per acre, denoted by R0, R1 and R2 respectively. All harvested stands are replanted and natural regeneration also assumed to occur.

Note: Any two treatments within a given stand will be at least 20 years apart

Upland areas

Stands newly established after a regeneration harvest were modeled with and without a subsequent thinning operation. Only one thinning operation (CT, AT and MT) was modeled for all stands with legacy trees (R1 and R2 stands); two commercial thinnings were modeled for R0 stands. Note: Woodstock has the option for nil, one or two thinnings. These are elective, not prescriptive. Two commercial thinning treatments or a commercial thinning and regeneration harvest were modeled at least 20 years apart.

Stands that are currently biologically and economically mature were grown within FVS, and the merchantable timber volumes were reported for regeneration harvests with nil, 10 or 20 legacy trees over the full range of potential regeneration harvest ages.

All stands that are regeneration harvested are planted and subject to subsequent natural regeneration.

Riparian Areas

Thinning in riparian areas is based on the WA Department of Natural Resources (2006) riparian desired future condition.

4.2.1 Treatment Specifications

The following treatment descriptions provide a linkage with between the actual harvest strategies employed by foresters, forest model assumptions, and potential environmental impacts. These descriptions are intended to supplement but not replace the more general ones found in *Standard Forestry Terms and Tree Names - A training and reference pamphlet for DNR Management of Forested Trust Lands* (DNR, March 2007) Actual harvest types over the next 10 to 20 years will not be limited to these descriptions, although most actual harvest will likely fall into one of these categories.

DNR is currently proposing to name all regeneration harvests as "variable retention harvests".

Table C14. Treatment descriptions

Forest Model Treatment Name	Timber Harvest Type	Sustainable harvest type (EIS terminology)	Notes	Reference
Commercial thinning (CT)	Commercial thinning	*Thinning*	Objective: Improve the stand condition and growth of the timber crop trees, maintain positive discounted cash-flow Target residual tree density: Curtis's RD 40 (±10) Methods: Thinning from below. The thinning is conducted to maintain an even spatial distribution of trees for full site utilization and maximum growth on all crop trees.	Holmberg and Aulds, 2007
MoRF and sub-mature habitat thinning treatment (MT)	Light variable density thinning	*Thinning*	Objective: Improve the stand condition and growth of the timber crop trees, maintain positive discounted cash-flow. In specific cases the treatment is used to develop northern spotted owl habitat (MoRF and sub-mature habitats). Target residual tree density: 125 trees per acre (±25) Methods: Thinning from below. The harvest treatment retains small areas of un-thinned trees, removes all trees in small gaps and thins the remainder of the stand with one of two or three residual densities levels to create vertical and horizontal variation across the forest stand canopy.	Holmberg and Aulds, 2007
Type A habitat thinning treatment	Heavy variable density thinning	*Partial harvest*	Objective: Improve the stand condition and growth of the timber crop trees, maintain positive discounted cash-flow In specific cases the treatment is used to develop northern spotted owl habitat (A-Type habitat or better). Target residual tree density: 75 trees per acre (±15) Methods: Thinning from below. The harvest treatment retains small areas of un-thinned trees, removes all trees in small gaps and thins the remainder of the stand with one of two or three residual densities levels to create vertical and horizontal variation across the forest stand canopy.	Holmberg and Aulds, 2007, Carey 2003

Forest Model Treatment Name	Timber Harvest Type	Sustainable harvest type (EIS terminology)	Notes	Reference
Regeneration harvest with 20 legacy trees	Variable Retention Harvest (VRH) – between 10 and 20 trees per acre	*Regeneration harvest*	Objective: Final harvest of the commercial cohort and regeneration of the next commercial cohort while retaining key structural elements of the existing stand. In some cases, the objective is high quality northern spotted owl habitat (high-quality nesting, Type A and B habitats) in others, visual management. Target residual density differs for this harvest type because a standard prescription would be insufficient for to manage the variety of cohorts. Regeneration is typically practiced through planting in openings and matching silvics to planted seedlings; site preparation is practiced as needed. Methods: The management activity area would encompass the all-continuous harvest units, including the riparian management areas and leave areas. A Variable Retention Harvest is characterized by at least three major purposes must be addressed in the silvicultural prescription objectives: (a) "lifeboating" of species and processes immediately after harvesting and before forest cover is reestablished; (b) "enriching" the reestablished forest stands with structural features that would otherwise be absent; and (c) "enhancing connectivity" in the managed landscape VRH is utilized in cases where a forest stand's response to commercial thinning (or other forms of harvest) is likely to be poor or there is a high risk of increased wind damage or forest health will deteriorate.	Franklin et. al., 1997

Forest Model Treatment Name	Timber Harvest Type	Sustainable harvest type (EIS terminology)	Notes	Reference
Regeneration harvest with 10 legacy trees	Variable Retention Harvest (VRH) – between 8 and 10 trees per acre	*Regeneration harvest*	Objective: Final harvest of the commercial cohort and regeneration of the next commercial cohort. Target residual density: 5 to 10 percent of the stand is retained post harvested, leaving a minimum of 8 large trees or more per acre (including the structurally unique and/or trees species such as western red cedar, Sitka spruce, and Pacific silver fir and conserving existing large snags (over 20 inches in diameter) and coarse woody debris (CWD)). Regeneration is typically though planting and establishment of the appropriate tree species to the site. Site preparation is practiced as needed.	Holmberg and Aulds, 2007

Residual tree density calculated for trees ≥3.5 inches dbh.

Table C15. Treatment Classes

Treatment Class	Description	Residual Trees Per Acre Post Treatment (4" ≤ dbh ≤ 30")	Target Residual Tree RD
1AT03	A-Type thinning	75	
1AT04	A-Type thinning	75	
1AT05	A-Type thinning	75	
1AT06	A-Type thinning	75	
1AT07	A-Type thinning	75	
1AT08	A-Type thinning	75	
1AT09	A-Type thinning	75	
1AT10	A-Type thinning	75	
1CT02	Commercial thinning		40
1CT03	Commercial thinning		40
1CT04	Commercial thinning		40
1CT05	Commercial thinning		40
1CT06	Commercial thinning		40
1CT07	Commercial thinning		40
1CT08	Commercial thinning		40
1CT09	Commercial thinning		40
1CT10	Commercial thinning		40
1CT20	Commercial thinning		40
1MT03	MoRF or Sub-mature thinning	125	
1MT04	MoRF or Sub-mature thinning	125	
1MT05	MoRF or Sub-mature thinning	125	
1MT06	MoRF or Sub-mature thinning	125	
1MT07	MoRF or Sub-mature thinning	125	
1MT08	MoRF or Sub-mature thinning	125	
1MT09	MoRF or Sub-mature thinning	125	
1MT10	MoRF or Sub-mature thinning	125	
1MT20	MoRF or Sub-mature thinning	125	
R0	Regeneration harvest with no legacy trees (clear cut)	0	
R0-1AT05	Future stand with A-Type thinning	75	
R0-1CT04	Future stand with Commercial thinning		40
R0-1CT05	Future stand with Commercial thinning		40
R0-1CT05-2	Future stand with Commercial thinning		40
R0-1CT06	Future stand with Commercial thinning		40
R0-1CT06-2	Future stand with Commercial thinning		40
R0-1CT07	Future stand with Commercial thinning		40
R0-1CT08	Future stand with Commercial thinning		40
R0-1CT09	Future stand with Commercial thinning		40
R0-1MT04	Future stand with MoRF thinning	125	
R0-1MT05	Future stand with MoRF thinning	125	
R0-1MT07	Future stand with MoRF thinning	125	
R0-1MT08	Future stand with MoRF thinning	125	
R1	Regeneration harvest with 10 legacy trees	10	
R1-1AT04	Future stand with A-Type thinning	75	
R1-1AT05	Future stand with A-Type thinning	75	

Treatment Class	Description	Residual Trees Per Acre Post Treatment (4" ≤ dbh ≤ 30")	Target Residual Tree RD
R1-1CT04	Future stand with Commercial thinning		40
R1-1CT05	Future stand with Commercial thinning		40
R1-1CT05-2	Future stand with 2ndCommercial thinning		40
R1-1CT06	Future stand with Commercial thinning		40
R1-1CT06-2	Future stand with 2ndCommercial thinning		40
R1-1CT07	Future stand with Commercial thinning		40
R1-1CT08	Future stand with Commercial thinning		40
R1-1MT04	Future stand with MoRF thinning	125	
R1-1MT05	Future stand with MoRF thinning	125	
R2	Regeneration harvest with 20 legacy trees	20	
R2-1CT05	Future stand with Commercial thinning		40
R2-1CT05-2	Future stand with 2ndCommercial thinning		40
R2-1CT06	Future stand with Commercial thinning		40
R2-1CT06-2	Future stand with 2ndCommercial thinning		40
R2-1CT07	Future stand with Commercial thinning		40
R2-1MT05	Future stand with MoRF thinning	125	
UT	Unthinned stand		

4.2.1.1   Commercial Thinning (CT)

Existing stands greater than 30 years of age

Objectives:
- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.

Prescription[4]: B-GEM-WH
- Thinning trigger: ≥ RD 65 (not a condition set in yield table generator)
- Thinning target: RD 45
- Thinning ratio: from below

FVS Keywords:

```
* 1st commercial thinning
IF                 0
 Int(Mod(Rx,100)/10) EQ 1 AND Int(Rx/100) EQ 0 AND Period EQ T1p
Then
ThinRDen           0      Parms(45., 1., All, 0., 999., 1)
ENDIF
```

Notes: An alternative prescription could be developed in the post process to reflect the addition of 3 snags per acre and 2,400 cubic feet per acre of coarse woody debris. Suitable notation in the yield should be applied as it is likely these types of additional treatment would only occur in HCP northern spotted conservation management areas (i.e. NRF and dispersal landscapes).

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[4] Holmberg, P. and B. Aulds. 2007. Developing Westside Silvicultural Prescriptions: an Inter-Active Self Study and Reference Pamphlet. Washington State Department of Natural Resources. Olympia, WA.

Regenerated stands and stands less than 30 years of age

Objectives:
- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.

Prescription: B-GEM-WH
- Thinning trigger: RD 65 (for trees ≥ 3.5 and ≤ 29 inches dbh)
- Thinning target: RD 45 (for trees ≥ 3.5 and ≤ 29 inches dbh)
- Thinning ratio: from below
- Tree diameters eligible for thinning: ≥ 3.5 and ≤ 29 inches dbh

FVS Keywords:

```
* 1st commercial thinning after regeneration cut
IF                  0
 Int(Mod(Rx,100)/10) EQ 1 AND Int(Rx/100) GT 0 AND Period EQ T1p
Then
ThinRDen           0      Parms(45., 1., All, 3.5, 29., 1)
ENDIF

* 2nd commercial thinning
IF                  0
 Mod(Rx,10) GT 0 AND Period EQ T2p
Then
ThinRDen           0      Parms(45, 1., All, 0., 999., 1)
ENDIF
```

Notes: Following 3 or more 10 year growth cycles, the 2nd commercial thinning would be simulated if stand conditions met or exceeded the same criteria for the 1st commercial thinning.

An alternative prescription could be developed in the post process to reflect the addition of 3 snags per acre and 2,400 cubic feet per acre of coarse woody debris. Suitable notation in the yield should be applied as it is likely these types of additional treatment would only occur in HCP northern spotted conservation management areas (i.e., Nesting, Roosting & Foraging and Dispersal landscapes).

4.2.1.2 Light Variable Density Thinning Treatment for MoRF and Sub-Mature Habitat (MT)

Existing stands greater than 30 years of age

Objectives:
1. Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth
2. Attain Movement, Roosting & Foraging (MoRF) and sub-mature habitat for northern spotted owls

Prescription:
- Thinning trigger: RD 65 for trees greater than or equal to 3.5 inch dbh (not a condition set in FVS)
- Thinning target: 125 trees per acre
- Thinning ratio: Variable density thinning (VDT)
- Snags and CWD treatment: 3 snags ≥ 20 inches added and 2,400 cubic feet per acre of coarse woody debris added.
- Understory development: assume that if removal of more than 40 percent of the pre-treatment basal area, 50 western hemlock trees per acre natural regenerate – survival at 90 percent.

FVS Keywords:

```
* NSO MoRF thinning or NSO MoRF thinning after regeneration cut
IF                  0
 Int(Mod(Rx,100)/10) EQ 2 AND Period EQ T1p
Then
ThinBTA           0      Parms(125., 1., 3.5, 29.0, 0., 999.)
* Simulate advanced regeneration
ThinBTA           0      Parms( 20., 1., 0.0,  3.5, 0., 999.)
ENDIF
```

ADD COMPUTE and POST PROCESS:
Add 3 20 inch SNAGS per acre
And
2400 cubic feet of coarse woody debris

Regenerated stands and stands less than 30 years of age

Objectives:
- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.
- Attain Movement, Roosting, & Foraging (MoRF) and sub-mature habitat for northern spotted owls

Prescription: B-GEM-WH
- Thinning trigger: RD 65 (for trees ≥ 3.5 and ≤ 29 inches dbh)
- Thinning target: RD 45 (for trees ≥ 3.5 and ≤ 29 inches dbh)
- Thinning ratio: from below
- Tree diameters eligible for thinning: ≥ 3.5 and ≤ 29 inches dbh
- Understory development: assume 15 trees per acre of advanced regeneration (0-7.5 inches dbh) survive harvesting treatment and that 200 western hemlock trees per acre naturally regenerated and 50 western red cedar trees per acre are planted – survival at 90 percent.
- Snags and CWD treatment: 3 snags ≥ 20 inches added and 2,400 cubic feet per acre of coarse woody debris added

FVS Keywords:

```
* NSO MoRF thinning only or NSO MoRF thinning after regeneration cut
IF                 0
 Int(Mod(Rx,100)/10) EQ 2 AND Period EQ T1p
Then
ThinBTA            0      Parms(125., 1., 3.5, 29.0, 0., 999.)
* Simulate advanced regeneration
ThinBTA            0      Parms( 20., 1., 0.0,  3.5, 0., 999.)
ENDIF
```

ADD COMPUTE and POST PROCESS:
Add 3 20 inch SNAGS per acre
And
2400 cubic feet of coarse woody debris

4.2.1.3   Heavy Variable Density Thinning Treatment for Type A Habitat and Older Forests (AT)

Existing stands greater than 30 years of age

Objectives:
- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of growth of residual trees
- Attain Type A habitat for northern spotted owls and/or older forest conditions

Prescription:
- Thinning trigger: RD ≥ 50 for trees greater than or equal to 3.5 inch dbh (not a condition set in FVS)
- Thinning target: 75 trees per acre between 7.5-999 inches dbh; 15 trees per acre between 0-7.5 inches dbh
- Thinning ratio: Variable density thinning (VDT)
- Understory development: assume 15 trees per acre of advanced regeneration (0-7.5 inches dbh) survive harvesting treatment and that 200 western hemlock trees per acre naturally regenerated and 50 western red cedar trees per acre are planted – survival at 90 percent.
- Snags and CWD treatment: 3 snags per acre ≥ 20 inches added and 2,400 cubic feet per acre of coarse woody debris added

FVS Keywords:

```
* NSO Type A thinning only or NSO Type A thinning
* after regeneration cut
IF                  0
 Int(Mod(Rx,100)/10) EQ 3 AND Period EQ T1p
Then
ThinBTA            0     Parms(75., 1., 7.5, 999., 0., 999.)
* Simulate advanced regeneration
ThinBTA            0     Parms(15., 1., 0.0, 7.5, 0., 999.)
* Natural regeneration
Estab
NoSprout
Natural            1     Parms(WH, 200., 60., 1., 0., 1)
Natural            1     Parms(RC,  50., 60., 1., 0., 1)
End
ENDIF
```

ADD COMPUTE and POST PROCESS:
Add 3 20 inch SNAGS per acre
And
2400 cubic feet of coarse woody debris

Regenerated stands and stands less than 30 years of age

Objectives:
- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.
- Attain Type A habitat for northern spotted owls and/or older forest conditions

Prescription:
- Thinning trigger: RD ≥ 50 for trees greater than or equal to 3.5 inch dbh (not a condition set in FVS)
- Thinning target: 75 trees per acre between 7.5-999 inches dbh; 15 trees per acre between 0-7.5 inches dbh
- Thinning ratio: Variable density thinning (VDT)
- Understory development: assume 15 trees per acre of advanced regeneration (0-7.5 inches dbh) survive harvesting treatment and that 200 western hemlock trees per acre naturally regenerated and 50 western red cedar trees per acre are planted – survival at 90 percent.
- Snags and CWD treatment: 3 snags per acre ≥ 20 inches added and 2,400 cubic feet per acre of coarse woody debris added

FVS Keywords:

```
* NSO Type A thinning only or NSO Type A thinning
* after regeneration cut
IF                 0
 Int(Mod(Rx,100)/10) EQ 3 AND Period EQ T1p
Then
ThinBTA            0     Parms(75., 1., 7.5, 999., 0., 999.)
* Simulate advanced regeneration
ThinBTA            0     Parms(15., 1., 0.0, 7.5, 0., 999.)
* Natural regeneration
Estab
NoSprout
Natural            1     Parms(WH, 200., 60., 1., 0., 1)
Natural            1     Parms(RC,  50., 60., 1., 0., 1)
End
ENDIF
```

ADD COMPUTE and POST PROCESS:
Add 3 20 inch SNAGS per acre
And
2400 cubic feet of coarse woody debris

4.2.1.4 Regeneration Harvests with 10 Residual Trees per Acre (R1)

Objectives:
- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.

Prescription:
- Harvest target: 10 trees per acre from largest cohort
- Thinning ratio: from below
- SNAGS and CWD: preserved
- Reforestation strategy: plant 250 Douglas-fir trees per acre, 50 western red cedar trees per acre with 90 percent survival; assume for FVS West Cascade variant 550 western hemlock trees per acre naturally seed in with 60 percent survival; for FVS Pacific Northwest variant assume 150 western hemlock trees per acre naturally seed in with 60 percent survival.

FVS Keywords:

```
* Regeneration cut
IF                 0
 Int(Rx/100) GT 0 AND Period EQ Cp
Then
* Arguments: ResTPA, CutEff, SmDBH, LgDBH, SmHt, LgHt
ThinBTA           0     Parms(ResTPA, 1., 0., 999., 0., 999.)
Estab
Plant             1DF               250.0      90.0        2.        1
Plant             1RC                50.0      90.0        2.        1
* Arguments: Species, trees, survival, age, Ht,
* ShadeCode 0=uniform, 1=shade, 2=sun
NoSprout
*Natural          10    Parms(WH, WHtpa, 60., 1., 0., 2)
Natural           1     Parms(WH, WHtpa, 60., 1., 0., 2)
End
```

4.2.1.5　　　Regeneration Harvests with 20 Residual Trees per Acre (R2)

Objectives:
- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.

Prescription:
- Harvest target: 20 trees from the largest cohort
- Thinning ratio: from below
- SNAGS and CWD: preserved
- Reforestation strategy: plant 250 Douglas-fir trees per acre, 50 western red cedar trees per acre with 90 percent survival; assume for FVS West Cascade variant 550 western hemlock trees per acre naturally seed in with 60 percent survival; for FVS Pacific Northwest variant assume 150 western hemlock trees per acre naturally seed in with 60 percent survival.

FVS Keywords:

```
* Regeneration cut
IF                 0
 Int(Rx/100) GT 0 AND Period EQ Cp
Then
* Arguments: ResTPA, CutEff, SmDBH, LgDBH, SmHt, LgHt
ThinBTA            0      Parms(ResTPA, 1., 0., 999., 0., 999.)
Estab
Plant              1DF                250.0       90.0       2.        1
Plant              1RC                 50.0       90.0       2.        1
* Arguments: Species, trees, survival, age, Ht,
* ShadeCode 0=uniform, 1=shade, 2=sun
NoSprout
*Natural           10     Parms(WH, WHtpa, 60., 1., 0., 2)
Natural            1      Parms(WH, WHtpa, 60., 1., 0., 2)
End
ENDIF
```

4.2.1.6   Planting / Natural Regeneration

Prescription:
- Plant 250 Douglas-fir trees per acre and 50 western red cedar trees per acre with a 90% survival rate for all regeneration harvest treatments.
- Naturally regenerate 550 western hemlock trees per acre for FVS West Cascade variant or 150 trees per acre for FVS Pacific Northwest variant with a 60% survival rate for all regeneration harvest treatment.
- Natural regeneration will occur regardless of treatments if the basal area is less than 200 ft^2/acre.
- Regardless the types of thinning, natural regeneration has been simulated if the basal area is less than 200 square feet per acre for live trees with a dbh ≥ 3.5 inches

FVS Keywords:

```
* Natural regeneration regardless treated or not
IF                 0
 BA3d5 LE 200 AND Period GE 1
Then
Estab
NoSprout
Natural            30     Parms(WH, 200., 60., 1., 0., 1)
Natural            30     Parms(RC,  50., 60., 1., 0., 1)
End
ENDIF
```

4.2.1.7 Pre-commercial Thinning (PCT)

Prescription:
- Upon completion of one 10-year growth cycle following a regeneration harvest, stands with more than 325 live trees per acre with dbh ≥ 8 inches were pre-commercially thinned.
- Upon completion of two 10-year growth cycles following a regeneration harvest, stands with more than 400 trees per acre were per-commercially thinned

FVS Keywords:

```
* Precommercial thinning
IF                   0
Int(Rx/100) GT 0 AND SpMcDBH(1,All,0,0.0,8.0, 0.0,999.0,0,0.) GT 325 &
 AND Period EQ Cp+1
Then
* Compute variables needed for routine. _CE1 and _CE2 are intermediate
* variables used to compute the cutting efficiency (CE).  Cutting
* efficiency variables are not used in ThinSDI and ThinCC keywords.
* T_SP and D_SP * represent the stand attribute of targeted and
* desired species, respectively.
Compute              0
D_SP = MAX(0,SPMCDBH(1,0,0,0.,999.)/PROPSTK- &
 SPMCDBH(1,All,0,0.,999.)/PROPSTK)
T_SP = SPMCDBH(1,All,0,0.,999.)/PROPSTK
_CE1 = 1.0-0.
_CE2 = T_SP-325.
_CE = linint(325.,1,1,1.0,linint(_CE1*T_SP,_CE2,_CE2,_CE2/T_SP,_CE1))
End
SPECPREF             0       All         50
TCONDMLT             0         5
ThinBTA              0     Parms((D_SP+325.),_CE,0.,999.,0,999)
!!ThinATA             0     Parms((D_SP+325.),_CE,0.,999.,0,999)
!!ThinABA             0     Parms((D_SP+325.),_CE,0.,999.,0,999)
!!ThinSDI             0     Parms(325.,1.0-0.,All,0.,999.,2)
!!ThinCC              0     Parms(325.,1.0-0.,All,0.,999.,2)
ENDIF
```

5.   YIELD TABLES

5.1   Scale and Structure of Yield Settings

The yield tables used for modeling South Puget Sound HCP forested lands are stratum based, age-dependent yield tables. *Stratum based yield tables* were used in place of specific yield tables for every management unit area. The yield tables were derived from tree level data for stands with the same unique combinations of stand and site characteristics, as outlined previously in section 3.

Stratum based modeling involves classifying the resource into homogeneous units, defined by groupings with similar forest crop attributes, silvicultural history and site quality. Administrative and management boundaries were not considered. Strata may be discontiguous or discrete contiguous units.

Age dependent yield tables report yield as a function of stand age. The yield tables contain values for each stand age in 10-year growth periods, including: harvested product volumes, stand parameters , and forest structural characteristics that are used to ascertain habitat quality. The full list of variables modeled are described in Table C16 below.

5.2   Yield table Variables

Table C16. Yield table variables

No	Variable	Description	Source
1	Accr	Accretion (ft³/acre)	FVS Compute: ACCR
2	AccrMort	Accretion-Mortality class	Post-process
3	Age	Stand age (years) = current year - origin year	FRIS and post-process
4	AgeCls	Age class = Int(age/10) + 1	Post-process
5	Area	Stand area (acres)	FRIS
6	BA	Basal area (ft²/acre) of all live trees (ft²/acre)	FVS Compute: BA
7	BA3d5	Basal area (ft²/acre) of live trees with DBH ≥ 3.5"	FVS Compute: BA3D5
8	BA7d5	Basal area (ft²/acre) of live trees with DBH ≥ 7.5"	FVS Compute: BA3D7
9	BAcns	Basal area (ft²/acre) of chip & saw with 7.5" ≤ DBH < 11.5" and height ≥ 16'	FVS Compute: BACNS
10	BAplp	Basal area (ft²/acre) of pulpwood with 4.5" ≤ DBH < 7.5" and height ≥ 16'	FVS Compute: BAPLP
11	BAsaw	Basal area (ft²/acre) of sawlog with DBH ≥ 11.5" and height ≥ 16'	FVS Compute: BASAW
12	BAswd	Basal area per acre (ft²/acre) of all softwoods with DBH ≥ 3.5"	FVS Compute: BASWD
13	BF	Volume (bf/acre) of all live trees	FVS Compute: BF
14	BF20	Volume (bf/acre) of live trees with DBH ≥ 19.5"	FVS Compute: BF20
15	BF3d5	Volume (bf/acre) of live trees with DBH ≥ 3.5"	FVS Compute: BF3D5
16	BF7d5	Volume (bf/acre) of live trees with DBH ≥ 7.5"	FVS Compute: BF7D5
17	BFcns	Volume (bf/acre) of chip & saw with 7.5" ≤ DBH < 11.5" and height ≥ 16'	FVS Compute: BFCNS
18	BFmv	Merchantable volume (bf/acre) with DBH ≥ 7.5" and height ≥ 16'	FVS Compute: BFMV

No	Variable	Description	Source
19	BFplp	Volume (bf/acre) of pulpwood with 4.5" ≤ DBH < 7.5" and height ≥ 16'	FVS Compute: BFPLP
20	BFsaw	Volume (bf/acre) of sawlog with DBH ≥ 11.5" and height ≥ 16'	FVS Compute: BFSAW
21	BPI	Berger-Parker Index = TPA_total/TPA_max	FVS Compute: BPI
22	BPI1TPA	Live trees per acre with 6.6' ≤ height < 13.1'	FVS Compute: BPI1TPA
23	BPI2TPA	Live trees per acre with 13.1' ≤ height < 26.2'	FVS Compute: BPI2TPA
24	BPI3TPA	Live trees per acre with 26.2' ≤ height < 52.5'	FVS Compute: BPI3TPA
25	BPI4TPA	Live trees per acre with 52.5' ≤ height < 105.0'	FVS Compute: BPI4TPA
26	BPI5TPA	Live trees per acre with 105.0' ≤ height < 157.5'	FVS Compute: BPI5TPA
27	BPI6TPA	Live trees per acre with 157.5' ≤ height < 210.0'	FVS Compute: BPI6TPA
28	BPI7TPA	Live trees per acre with height ≥ 210.0'	FVS Compute: BPI7TPA
29	CC	Canopy cover (%/acre)	FVS Compute: CC
30	CC3d5	Canopy cover (%/acre) of live trees with DBH ≥ 7.5"	FVS Compute: CC3D5
31	CC7d5	Canopy cover (%/acre) of live trees with DBH ≥ 3.5"	FVS Compute: CC7D5
32	CF	Volume (ft^3/acre) of all live trees	FVS Compute: CF
33	CF20	Volume (ft^3/acre) of live trees with DBH ≥ 19.5"	FVS Compute: CF20
34	CF3d5	Volume (ft^3/acre) of live trees with DBH ≥ 3.5"	FVS Compute: CF3D5
35	CF7d5	Volume (ft^3/acre) of live trees with DBH ≥ 7.5"	FVS Compute: CF7D5
36	CFcns	Volume (ft^3/acre) of chip & saw with 7.5" ≤ DBH < 11.5" and height ≥ 16'	FVS Compute: CFCNS
37	CFmv	Merchantable volume (ft^3/acre) with DBH ≥ 7.5" and height ≥ 16'	FVS Compute: CFMV
38	CFplp	Volume (ft^3/acre) of pulpwood with 4.5" ≤ DBH < 7.5" and height ≥ 16'	FVS Compute: CFPLP
39	CFsaw	Volume (ft^3/acre) of sawlog with DBH ≥ 11.5" and height ≥ 16'	FVS Compute: CFSAW
40	CrnDept	Crown depth of the top strata with canopy cover ≥ 5%	FVS Compute: CRNDEPT
41	CrnLift	Crown lift of the bottom strata with canopy cover ≥ 5%	FVS Compute: CRNLIFT
42	CWDv	Volume (ft³/acre) of coarse woody debris	FVS Compute: CWDV
43	DBHavg	Estimated average of DBH for all live trees per acre	Post-process
44	DBHcv	Estimated coefficient of variance of DBH for all live trees per acre	Post-process
45	DBHskew	Estimated skewness of DBH for all live trees per acre	Post-process
46	DBHstd	Estimated standard deviation of DBH for all live trees per acre	Post-process
47	DDI	Diameter diversity index	FVS Compute: DDI
48	DDI1TPA	Live trees per acre with 2" ≤ DBH < 9.8" (median TPA = 295, weight = 1)	FVS Compute: DDI1TPA
49	DDI2TPA	Live trees per acre with 9.8" ≤ DBH < 19.7" (median TPA = 87, weight = 2)	FVS Compute: DDI2TPA
50	DDI3TPA	Live trees per acre with 19.7" ≤ DBH < 39.4" (median TPA = 70, weight = 3)	FVS Compute: DDI3TPA
51	DDI4TPA	Live trees per acre with DBH ≥ 39.4" (median TPA = 28, weight = 4)	FVS Compute: DDI4TPA
52	FDS1	Forest development stage - definition 1	Post-process
53	FDS2	Forest development stage - definition 2	Post-process
54	ForType	Forest type (2 or 4 letters)	FRIS and post-process
55	FSHabTyp	Habitat type defined by USFS	FVS Compute: HABFS
56	HabDis	Dispersal habitat (1 = yes, 0 = no)	FVS Compute: HABDIS
57	HabHQN	High-quality nesting habitat (1 = yes, 0 = no)	FVS Compute: HABHQN
58	HabI	Habitat index (range: 0 - 127)	FVS Compute: HABI
59	HabMRF	Movement of Roosting Foraging Habitat (1 = yes, 0 = no)	FVS Compute: HABMRF

No	Variable	Description	Source
60	HabSoA	Type A spotted owl habitat (1 = yes, 0 = no)	FVS Compute: HABSOA
61	HabSoB	Type B spotted owl habitat (1 = yes, 0 = no)	FVS Compute: HABSOB
62	HabSub	Sub-mature habitat (1 = yes, 0 = no)	FVS Compute: HABSUB
63	HabYFM	Young forest marginal habitat (1 = yes, 0 = no)	FVS Compute: HABYFM
64	HT	Average height (ft) of all live trees	FVS Compute: HTAVG
65	HT3d5	Average height (ft) of live trees with DBH ≥ 3.5"	FVS Compute: HT3D5
66	HT7d5	Average height (ft) of live trees with DBH ≥ 7.5"	FVS Compute: HT7D5
67	HTcns	Average height (ft) of chip & saw with 7.5" ≤ DBH < 11.5" and height ≥ 16'	FVS Compute: HTCNS
68	HTplp	Average height (ft) of pulpwood with 4.5" ≤ DBH < 7.5" and height ≥ 16'	FVS Compute: HTPLP
69	HTsaw	Average height (ft) of sawlog with DBH ≥ 11.5" and height ≥ 16'	FVS Compute: HTSAW
70	Mort	Mortality (ft³/acre)	FVS Compute: DEAD
71	NoHtCls	Number of height class	FVS Compute: NOHTCLS
72	NoHtStra	Number of height strata with height differences ≥ 15% and canopy cover ≥ 5%	FVS Compute: NOHTSTRA
73	NoSpp	Number of species per acre with percentage live trees ≥ 5% and DBH >= 3.5"	FVS Compute: NOSPP
74	OFC1TPA	Live trees per acre with 0" ≤ DBH < 3.5"	FVS Compute: OFC1TPA
75	OFC2TPA	Live trees per acre with 3.5" ≤ DBH < 11.5"	FVS Compute: OFC2TPA
76	OFC3TPA	Live trees per acre with 11.5" ≤ DBH < 19.5"	FVS Compute: OFC3TPA
77	OFC4TPA	Live trees per acre with 19.5" ≤ DBH < 29.5"	FVS Compute: OFC4TPA
78	OFC5TPA	Live trees per acre with DBH ≥ 29.5"	FVS Compute: OFC5TPA
79	OFCI	Older forest condition index (range: 0 - 31)	FVS Compute: OFCI
80	PAI	Periodic annual increment (ft³/acre) = accretion - mortality	Post-process
81	PBAswd	Percentage basal area per acre (ft²/acre) of all softwoods with DBH ≥ 3.5"	Post-process
82	Period	Time index (10-year increment)	FVS Compute: PERIOD
83	PTPAswd	Percentage live trees per acre of softwoods with DBH ≥ 3.5"	FVS Compute: PTPASWD
84	QMD	Quadratic mean diameter (inches) of all live trees per acre	Formula: $24 \times \mathrm{Sqrt}(BA/TPA/4/Atn(1))$
85	QMD100	Estimated quadratic mean diameter (inches) of 100 largest live trees per acre	FVS Compute: QMD100
86	QMD3d5	Quadratic mean diameter (inches) of lives trees with DBH ≥ 3.5"	FVS Compute: QMD3D5
87	QMD7d5	Quadratic mean diameter (inches) of lives trees with DBH ≥ 7.5"	Formula: $24 \times \mathrm{Sqrt}(BA7d5/TPA7d5/4/Atn(1))$
88	Rate4R	Rating for possible regeneration cut treatment	Post-process
89	Rate4T	Rating for possible thinning treatment	Post-process
90	RD	Curtis' relative density	FVS Compute: RD
91	RD3d5	Relative density of live trees per acre with DBH ≥ 3.5"	FVS Compute: RD3D5
92	RD7d5	Relative density of live trees per acre with DBH ≥ 7.5"	Formula: $BA7d5/\mathrm{Sqrt}(QMD7d5)$
93	RIU_ID	Current resource inventory ID	FRIS
94	Rx	Regime code	FVS Compute: RX
95	SDI	Stand density index = $TPA/(QMD/10)^{1.605}$	Post-process
96	SDI3d5	SDI of live trees per acre with DBH ≥ 3.5"	FVS Compute: SDI3D5
97	SDI7d5	SDI of live trees per acre with DBH ≥ 7.5"	FVS Compute: SDI7D5
98	SI	Site index (ft) at breast height age 50	FRIS and post-process
99	SIC	Site index class	Post-process

No	Variable	Description	Source
100	SizeCls	QMD class by live trees per acre with DBH ≥ 3.5"	Post-process
101	Snag15	Snags per acre with diameter ≥ 14.5" and length ≥ 16'	FVS Compute: SNAG15
102	Snag20	Snags per acre with diameter ≥ 19.5" and length ≥ 16'	FVS Compute: SNAG20
103	Snag21	Snags per acre with diameter ≥ 20.5" and length ≥ 16'	FVS Compute: SNAG21
104	Snag30	Snags per acre with diameter ≥ 29.5" and length ≥ 16'	FVS Compute: SNAG30
105	StandID	Stand ID (same as master resource inventory ID, but in text type)	FVS Compute: StandID
106	StkCls	RD class by live trees per acre with DBH ≥ 3.5"	Post-process
107	Strata	ForType_SIC_StkCls_SizeCls_Rx	FRIS and post-process
108	StrCls	Structural class	FVS Compute: STRCLS
109	StrName	Name of structural class	Post-process
110	TopHt	Average height (ft) of 40 largest live trees on an acre	FVS Compute: TOPHT
111	TPA	Live trees per acre (trees/acre)	FVS Compute: TPA
112	TPA0002	Live trees per acre with 0" ≤ DBH < 2"	Post-process
113	TPA20	Live trees per acre with DBH ≥ 19.5"	FVS Compute: TPA20
114	TPA21	Live trees per acre with DBH ≥ 20.5"	FVS Compute: TPA21
115	TPA30	Live trees per acre with DBH ≥ 29.5"	FVS Compute: TPA30
116	TPA31	Live trees per acre with DBH ≥ 30.5"	FVS Compute: TPA31
117	TPA3d5	Live trees per acre with DBH ≥ 3.5"	FVS Compute: TPA3D5
118	TPA40	Live trees per acre with DBH ≥ 39.5"	FVS Compute: TPA40
119	TPA7d5	Live trees per acre with DBH ≥ 7.5"	FVS Compute: TPA7D5
120	TPAalder	Live trees per acre of the "alder" group with DBH ≥ 3.5"	FVS Compute: TPAALDER
121	TPAcns	Live trees per acre of chip & saw with 7.5" ≥ DBH < 11.5"	FVS Compute: TPACNS
122	TPAdfir	Live trees per acre of the "Douglas-fir" group with DBH ≥ 3.5"	FVS Compute: TPADFIR
123	TPAhwd	Live trees per acre of all hardwoods with DBH ≥ 3.5"	FVS Compute: TPAHWD
124	TPAmxhwd	Live trees per acre of the "mixed hardwoods" group with DBH ≥ 3.5"	FVS Compute: TPAMXHWD
125	TPAmxswd	Live trees per acre of the "mixed softwoods" group with DBH ≥ 3.5"	FVS Compute: TPAMXSWD
126	TPApicea	Live trees per acre of the "picea" group with DBH ≥ 3.5"	FVS Compute: TPAPICEA
127	TPApine	Live trees per acre of the "pine" group with DBH ≥ 3.5"	FVS Compute: TPAPINE
128	TPAplp	Live trees per acre of pulpwood with 4.5" ≤ DBH < 7.5"	FVS Compute: TPAPLP
129	TPAsaw	Live trees per acre of sawlog with DBH ≥ 11.5"	FVS Compute: TPASAW
130	TPAswd	Live trees per acre of all softwoods with DBH ≥ 3.5"	FVS Compute: TPASWD
131	TPAwwd	Live trees per acre of the "white wood" group with DBH ≥ 3.5"	FVS Compute: TPAWWD
132	YrOrg	Origin year	FRIS and post-process

6.   FINANCIAL ASSUMPTIONS

The costs and revenues used within the model are current day real prices, assumed to remain constant over the 100 year planning horizon. Inflationary adjustments and real changes were excluded.

The forest modeling is structured to maximize the discounted net present value (NPV), so the DNR pre-tax real discount rate of 5% was applied. Since 10 year planning periods are used for the computer modeling. Within each 10 year period the silvicultural costs incurred and revenues are assumed to occur equally each year. In accordance with periodic financial modeling convention, the annual cashflow within each period was discounted from the mid-point of each period

6.1   Revenue

Prices used in Woodstock woody supply forecasting and harvest scheduling are listed in Table C17 below. Stumpage prices are based on an analysis of DNR timber sale prices received between 1999 and 2004, inclusive, and were used in the 2004 sustainable harvest analysis. *Saw* prices are based on regeneration harvest stumpage values; *pulp* prices are based on small-wood, commercial thinning DNR stumpage values; and *chip and saw* (CNS) prices are based on older-stand thinning stumpage values.

Table C17. Stumpage prices used in Woodstock wood supply forecasting and harvest scheduling

Forest Type	Stumpage Price ($ / MBF)		
	Saw	CNS	Pulp
DFRA	321	160	111
DFRC	478	278	166
DFWH	332	233	132
RADF	296	173	108
WHDF	286	174	106
WHRA	175	92	68
WHRC	415	219	161
WHSF	212	88	82
Other	286	174	106

Pulp: 4" ≤ dbh < 8"
CNS: 8" ≤ dbh < 12"
Saw: dbh ≥ 12"

6.2 Costs

Table C18. 2004 base year costs.

Operation	Cost	Units
Regeneration harvest	18.00	$ per MBF
Thinning	54.00	$ per MBF
Indirect variable DNR costs for harvesting operations	307.84	$ per acre
Stand establishment planting cost ($0.50 per seedling, 300-400 seedlings per acre)	175.00	$ per acre
Brush control, typically applied twice between 4 and 12 years	160.00	$ per acre
Pre-commercial thinning	160.00	$ per acre
Fertilization (Douglas-fir stands only)	90.00	$ per acre

7. MODELING ALTERNATIVES FOR PUGET SOUND

DNR's conservation objective for the northern spotted owl (NSO) is to provide habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal. Demographic support refers to the contribution of individual territorial spotted owls or clusters of spotted sites to the stability and viability of the entire population. Maintenance of species distribution refers to supporting the continued presence of the spotted owl in as much of its historic range as possible. Dispersal is the movement of juvenile, sub-adult, and adult spotted owls from one sub-population to another.

The intent of the spotted owl conservation strategy within the west-side HCP planning units (including the South Puget HCP planning unit) is twofold. First, the strategy is intended to provide nesting, roosting, and foraging (NRF) habitat and dispersal habitat in strategic areas in order to achieve the conservation objective. Second, in areas designed to provide NRF habitat, the strategy is intended to create a landscape in which active forest management plays a role in the development and maintenance of the structural characteristics that constitute such habitat (WDNR 1997).

The South Puget HCP planning unit contains approximately half (roughly 70,000 acres) of the designated dispersal management areas on state lands managed under the HCP. As a result of past timber management activities, forests within these areas are currently dominated by *competitive exclusion* and *understory development* stage forests, and young, overstocked second growth stands. In general, current forest conditions do not contribute to the habitat requirements of dispersing northern spotted owls.

DNR examined three approaches to managing designated dispersal management areas to meet the conservation objectives of the 1997 Habitat Conservation Plan. Different management scenarios were evaluated to create and enhance dispersal habitat. All three management alternatives follow the provisions outlined in the "Settlement Agreement"), that no Type A or Type B high quality habitat will be harvested.

Alternatives Related to Northern Spotted Owl Conservation include
- Alternative A - No Action
- Alternative B - Preferred Direction
- Alternative C - Exploratory Options

7.1 Scenario Description

7.1.1 Alternative A – No Action

Under Alternative A, DNR evaluated current management of designated dispersal areas. Dispersal habitat was defined according to minimum characteristics outlined in the HCP; a target condition was to maintain at least 50 percent of each spotted owl management unit (SOMU) in dispersal habitat; and following the Sept. 6, 2006 concurrence letter between DNR and the USFWS, habitat enhancement activities are permitted in certain dispersal habitat areas once within a 10 to 15 year period to enhance poorly functioning habitat.

7.1.2 Alternative B – Preferred Direction

Under Alternative B, DNR incorporated into dispersal management the northern spotted owl life history requirements of roosting and foraging. The target condition of movement, roosting, and foraging (MoRF) habitat is similar to the HCP definition of sub-mature[5] habitat, with the following additional requirements:

- 5 percent coarse woody debris (CWD) ground cover
- at least two canopy layers,
- 15" dbh minimum snag diameter (changed from 20" dbh) with a minimum height of 16'

The 50 percent threshold habitat target condition is applied at the level of the landscape unit rather than the SOMU. Distribution of habitat is tracked through monitoring associated with the planning process. This alternative allows for increased active management in the currently non-functioning dispersal habitat, placing such areas on a development trajectory toward MoRF habitat. Snag creation techniques are utilized during multiple entries. Current MoRF habitat, or higher quality northern spotted owl habitat will not be available for management activities that remove them from their current condition until the 50 percent landscape habitat target is met.

7.1.3 Alternative C – Exploratory Options

Under Alternative C, DNR explored other ways to manage dispersal habitat within the context of the HCP. All the life history requirements of northern spotted owls (nesting, roosting, foraging, and dispersal) were incorporated into this alternative. A target threshold of 50 percent MoRF or better habitat is applied at the landscape unit level. Within this 50 percent, 2/3 (or 30 percent of the total landscape area) is targeted to be Type B[6] or better habitat. Current MoRF or better habitat will not be available for management activities that remove them from their current condition until the 50 percent landscape habitat target is met. All existing high-quality nesting habitat is deferred from harvest. Distribution of habitat is tracked through monitoring associated with the planning process. Multiple entries are used to create snags, recruit coarse woody debris (CWD), and increase the diameter of the dominant trees.

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[5] Sub-mature habitat (west side planning units) has the following characteristics: (1) forest community dominated by conifers, or in mixed conifer/hardwood forests, the community is composed of at least 30 percent conifers (measured as stems per acre dominant, co-dominant, and intermediate trees); (2) at least 70 percent canopy closure; (3) tree density between 115 and 280 trees per acre (all greater than 4 inches dbh); (4) height of dominant and co-dominant trees at least 85 feet tall; and (5) at least three snags or cavity trees per acre that are 20 inches dbh. (DNR 1997, Trust Lands HCP, IV 12.)

[6] Type B habitat (west side planning units) has the following characteristics: (1) Few canopy layers, multispecies canopy dominated by large (greater than 20 inches dbh), overstory trees (typically 75-100 trees per acre, but can be fewer if larger trees are present; (2) greater than 70 percent canopy closure; (3) some large trees with various deformities; (4) large (greater than 20 inches dbh) snags present; and (5) accumulations of fallen trees and other woody debris on the ground. (DNR 1997, Trust Lands HCP, IV. 11.)

7.2   Representing Non-Spatial Policy and Procedures

7.2.1 Harvesting Settings

Table C19. Harvesting settings

	Alternative		
	A	**B**	**C**
General thinning prescriptions			
	GROUP 1 (Hoodsport, Belfair, and Snoqualamie) thinning up to 50 years in all upland land classes	GROUP 1 (Hoodsport, Belfair, and Snoqualamie) thinning up to 50 years in all upland land classes	GROUP 1 (Hoodsport, Belfair, and Snoqualamie) thinning up to 100 years in all upland land classes
	GROUP 2 (Elbe-District, Black Diamond) thinning up to 100 years on all upland land classes	GROUP 2 (Elbe-District, Black Diamond) thinning up to 100 years on all upland land classes	GROUP 2 (Elbe-District, Black Diamond) thinning up to 100 years on all upland land classes
	Riparian land class (GROUP 1 and 2) only thinning up to age 70 years	Riparian land class (GROUP 1 and 2) only thinning up to age 100 years	Riparian land class (GROUP 1 and 2) only thinning up to age 100 years
Specific thinning restrictions			
Tahoma	No thinning to residual densities below RD 40 in low site class (SIC4) WH dominated stands	No thinning to residual densities below RD 40 in low site class (SIC4) WH dominated stands	No thinning to residual densities below RD 40 in low site class (SIC4) WH dominated stands
Concurrence Sales	VDT Light Intensity Thinning permitted in concurrence sales (identified in deferral code 6th position character = "C")	N/A	N/A VDT Light Intensity Thinning permitted in concurrence sales (identified in deferral code 6th position character = "C")
Visual Areas	Regeneration harvests with 20 legacy trees (R2) in Elbe Hills visual areas (identified with "V" flag in Land Class code)	Regeneration harvests with 20 legacy trees (R2) in Elbe Hills visual areas (identified with "V" flag in Land Class code)	Regeneration harvests with 20 legacy trees (R2) in Elbe Hills visual areas (identified with "V" flag in Land Class code)
Tiger Mountain	Regeneration harvest limited to 600 acres per year	Regeneration harvest limited to 600 acres per year	Regeneration harvest limited to 600 acres per year
Existing Northern Spotted Owl (NSO) habitat			
High Quality Nesting, Type A Habitat, Type B Habitat	Regeneration harvest or thinning operations prohibited		
Movement, Roosting & Foraging (MoRF), Sub-Mature, Young Forest Marginal, Dispersal	Commercial thinning	Commercial thinning, Variable Density Thinning (light & heavy)	Commercial thinning, Variable Density Thinning (light & heavy)
Next Best	Commercial thinning	Commercial thinning, Variable Density Thinning (light & heavy)	N/A
Deferrals from harvest activities			
For entire planning period	Lands slated for transfer to NRCA/NAP (identified in X_ACTION_TY = "T")_lock 99	Lands slated for transfer to NRCA/NAP (identified in X_ACTION_TY = "T")_lock 99	Lands slated for transfer to NRCA/NAP (identified in X_ACTION_TY = "T")_lock 99
For period 1 only	Recent thinning harvest (SOLD_CD ≥ 2) _ Lock 1	Recent thinning harvest (SOLD_CD ≥ 2) _ Lock 1	Recent thinning harvest (SOLD_CD ≥ 2) _ Lock 1

Note: VDT Light Thinning is designed to create MoRF habitat, VDT Heavy Thinning is designed to create Type A habitat

7.2.2 Production Commitments

Table C20. Sustainable harvest targets (mbf) by decade

10 Year Period	Total Federal Granted Trust and State Forest Board Purchased Lands	Total Forest Board	Total South Puget HCP Planning Unit Harvest
1	144,983	120,754	265,737
2	181,779	160,359	342,138
3	180,092	184,709	364,801
4	431,066	343,537	774,603
5	183,293	209,410	392,703
6	157,027	167,626	324,653
7	237,376	214,173	451,549
8	254,278	243,583	497,861
9	332,624	267,180	599,804
10	419,920	314,839	734,759

Note: South Puget Sound HCP Planning Unit 2007 sustainable harvest level for decade 1 (2004-2014) ≥ 265,000 mbf. Federal Granted Trust and State Forest Board Purchased Lands 2007 sustainable harvest for decade 1 (2004-2014) = 30,828 mbf

Table C21. Sustainable harvest targets (mbf) by decade: Federal Granted Trust and State Forest Board purchase lands by county

10 Year Period	Federal Granted Trust and State Forest Board Purchased Lands by County										
	King	Kitsap	Lewis (SPS)	Lewis (PC)	Mason	Pierce	Snohom (SPS)	Snohom. (NW)	Thurst (SPS)	Thurst (PC)	Total
1	30,428	19,498	13,231	76	41,416	15,964		1,041	448	22,881	144,983
2	23,257	16,844	31,723	48	40,135	32,542		702	6	36,522	181,779
3	29,507	24,680	20,306	136	29,895	47,852		140	15	27,561	180,092
4	117,672	13,059	129,970	4,798	13,571	122,841	1,247	680	27	27,201	431,066
5	23,961	28,175	30,296	115	18,218	50,615			6	31,907	183,293
6	32,347	10,058	31,210	3,447	22,957	39,015		115	1	17,877	157,027
7	47,733	22,441	46,369	527	27,683	57,255		1,043	66	34,259	237,376
8	53,900	19,713	36,256	540	35,956	78,327		2,101	35	27,450	254,278
9	59,614	21,892	72,717	256	54,256	81,813			8	42,068	332,624
10	68,338	51,834	66,024	461	70,631	97,608	1,766	833	147	62,278	419,920

Note: Some counties span HCP planning unit boundaries and/or DNR Region boundaries. Targets shown above only include areas within either the South Puget HCP Planning Unit or the South Puget Sound Region.

Table C22. Sustainable harvest targets (mbf) by decade: State Forest Board transfer by county

10 Year Period	Forest Board Transfer by County										
	King	Kitsap	Lewis (SPS)	Lewis (PC)	Mason	Pierce	Snohom (SPS)	Snohom (NW)	Thurst (SPS)	Thurs. (PC)	Total
1	25,384	25,281	2,965		32,670	12,377			1,683	20,394	120,754
2	23,738	30,369	6,835		47,506	20,538			1,553	29,820	160,359
3	33,389	39,180	2,458	2	71,504	15,801			2,068	20,307	184,709
4	40,127	33,220	70,654	254	83,962	82,830			1,348	31,142	343,537
5	17,673	17,567	23,127		97,578	29,277			1,327	22,861	209,410
6	24,906	26,686	18,183		48,827	29,876			3,992	15,156	167,626
7	29,959	32,678	17,812	52	65,447	32,193			2,669	33,363	214,173
8	30,697	39,995	30,770		69,838	42,912			1,860	27,511	243,583
9	31,873	32,376	30,786	1,553	99,730	42,002			2,107	26,753	267,180
10	37,389	56,608	26,338		71,799	53,553			5,466	63,686	314,839

Note: Some counties span HCP planning unit boundaries and/or DNR Region boundaries. Targets shown above only include areas within either the South Puget HCP Planning Unit or the South Puget Sound Region

7.2.3 Forest Management and Silvicultural Policy

Table C23. Forest management and silvicultural policy

	Alternative		
	A	**B**	**C**
Objective	Maximize discounted net revenue	Maximize discounted net revenue	Maximize discounted net revenue
Discount rate	5%	5%	5%
Cashflow Constraint	N/A	+/- 10%	N/A
Sustainable Harvest Production Minimum Targets	South Puget Sound HCP unit 2007 sustainable harvest level of 265,000 MBF for decade 1 (2004-2014). (approximated in model as 2017)	South Puget Sound HCP unit 2007 sustainable harvest level of 265,000 MBF for decade 1 (2004-2014). (approximated in model as 2017)	South Puget Sound HCP unit 2007 sustainable harvest level of 265,000 MBF for decade 1 (2004-2014). (approximated in model as 2017)
	SPS Region harvest level 514,900 MBF for decade 1. Combined SPS HCP and Region = 559,300 MBF for decade 1.	SPS Region harvest level 514,900 MBF for decade 1. Combined SPS HCP and Region = 559,300 MBF for decade 1.	SPS Region harvest level 514,900 MBF for decade 1. Combined SPS HCP and Region = 559,300 MBF for decade 1.
	Federal Granted Trust and State Forest Board Purchased lands - production commitments applicable periods 1 - 10.	Federal Granted Trust and State Forest Board Purchased lands - production commitments applicable period 1 only.	Federal Granted Trust and State Forest Board Purchased lands - production commitments applicable period 1 only.
	2007 sustainable harvest levels for Forest Board Transfer by County - production targets applicable periods 1 - 10.	2007 sustainable harvest levels for Forest Board Transfer by County - production targets applicable period 1 only.	2007 sustainable harvest levels for Forest Board Transfer by County - production targets applicable period 1 only.
Replant constraint	Replanting constraint to ensure planting occurs on 100% of regeneration harvested areas - WA Forest Practices requirement	Replanting constraint to ensure planting occurs on 100% of regeneration harvested areas - WA Forest Practices requirement	Replanting constraint to ensure planting occurs on 100% of regeneration harvested areas - WA Forest Practices requirement
Long-term Sustainable harvest volume flow per Policy for Sustainable Forests	+/- 25% county production levels between periods	+/- 25% county production levels between periods	+/- 25% county production levels between periods
Permissible silviculture	Include Regeneration harvest (R1 on all sites and R2 for visual sites), commercial thinning (CT), MoRF habitat thinning (MT) and Type A habitat thinning (AT). Exclude R0 and PCT	Include Regeneration harvest (R1 on all sites and R2 for visual sites), commercial thinning (CT), MoRF habitat thinning (MT) and Type A habitat thinning (AT). Exclude R0 and PCT	Include Regeneration harvest (R1 on all sites and R2 for visual sites), commercial thinning (CT), MoRF habitat thinning (MT) and Type A habitat thinning (AT). Exclude R0 and PCT

7.2.4 Northern Spotted Owl Habitat Policies

Table C24. Northern spotted owl habitat policies

	Alternative		
	A	**B**	**C**
Settlement Agreement	No loss of existing NSO habitat below 50% of SOMU area between 2007-2014 (approximated in model as 2017) as per the Settlement Agreement. If SOMU contains more than 50% habitat (Busy Wild and Reese SOMUs) then excess of habitat (D, Y, S, U, N, X) can be regeneration harvested. If the habitat area is less than 50% of the SOMU, thinning to RD3d5 ≥ 48 is permitted but regeneration harvesting is not. Applicable Model Period I only. Harvesting is permanently deferred in all Type A and Type B habitat. (Locked 99 periods).	No loss of MoRFand better NSO habitat below 50% of SOMU area between 2007-2014 (approximated in model as 2017) as per the Settlement Agreement. If SOMU contains more than 50% habitat (Busy Wild and Reese SOMUs) then excess of habitat (Sub-mature and MoRF) can be regeneration harvested. If the habitat area is less than 50% of the SOMU, thinning to RD3d5 ≥ 48 is permitted in NSO habitat but regeneration harvesting is not. Applicable Model Period I only. Harvesting is permanently deferred in all Type A and Type B habitat. (Locked 99 periods).	No loss of MoRFand better NSO habitat below 50% of SOMU area between 2007-2014 (approximated in model as 2017) as per the Settlement Agreement. If SOMU contains more than 50% habitat (Busy Wild and Reese SOMUs) then excess of habitat (Sub-mature and MoRF) can be regeneration harvested. If the habitat area is less than 50% of the SOMU, thinning to RD3d5 ≥ 48 is permitted in NSO habitat but regeneration harvesting is not. Applicable Model Period I only. Harvesting is permanently deferred in all Type A and Type B habitat. (Locked 99 periods).
Concurrence Letter	Maintain area of existing NSO dispersal-plus habitat (D, Y, S, U, N, X) excluded from concurrence sales with RD3d ≥48. (No loss of dispersal habitat if thin down to RD =48). Can thin forest (Habitat D, Y, S, U, N, X) down to RD3d5 = 40 in stands approved under the concurrence letter. Applicable in model Period I only.	N/A	N/A
HCP Nesting, Roosting & Foraging	Current procedure to maintain 50 percent of Nesting Roosting and Foraging (NRF) habitat class (Sub-mature plus) in the Green, Pleasant Valley, North & South Snoqualimie Spotted Owl Management Units (SOMU). Applicable Whole Planning Period.	Current procedure to maintain 50 percent of Nesting Roosting and Foraging (NRF) habitat class (Sub-mature plus) in the Green, Pleasant Valley, North & South Snoqualimie Spotted Owl Management Units (SOMU). Applicable Whole Planning Period.	Current procedure to maintain 50 percent of Nesting Roosting and Foraging (NRF) habitat class (Sub-mature plus) in the Green, Pleasant Valley, North & South Snoqualimie Spotted Owl Management Units (SOMU). Applicable Whole Planning Period.
HCP Dispersal, MoRF and Type B	Current procedure - Each Spotted Owl Management Unit (SOMU) based on modified 1996 Watershed Administrative Unit (WAU) targeted to restore and maintain 50 percent of its area in a dispersal or better habitat class (HQN, A,B MoRF, S,Y,D). Applicable Whole Planning Period.	Each Spotted Owl Management Landscape targeted to restore and maintain 50 percent of its area in a Movement Roosting and Foraging (MoRF) or better (HQN, A, B) habitat class. Elbe, Enmuclaw, and Tahoma LPU's. Pleasant Valley Dispersal SOMU maintain at least 50% dispersal habitat	Each Spotted Owl Management Landscape targeted to restore and maintain at least 50 percent of its area in a Movement Roosting and Foraging (MoRF) or better (HQN, A,B) habitat class. Target of 20 percent MoRF habitat in Elbe, Enmuclaw, and Tahoma LPU's Target of 30 percent Type B habitat in Elbe, Enmuclaw, and Tahoma LPU's Pleasant Valley Dispersal SOMU maintain at least 50% dispersal habitat

7.2.5 Forest Landscape Management Policies

Table C25. Forest landscape management policies

| | Alternative | | |
	A	B	C
Rain on snow sub-basin targets	Target forecast of hydrological maturity (RD ≥ 25) in Rain-On-Snow basins at least 66% of Rain-On-Snow basin total area.	Target forecast of hydrological maturity (RD ≥ 25) in Rain-On-Snow basins at least 66% of Rain-On-Snow basin total area.	Target forecast of hydrological maturity (RD ≥ 25) in Rain-On-Snow basins at least 66% of Rain-On-Snow basin total area.
Upland management constraint representing management in sensitive areas	Forecast target of 80% of UPLANDS area in each watershed (WAU) that has Relative Density ≥ 48 Thinning Group No. 1: WAU RD ≥ 48, SOMU RD ≥ 25 Thinning Group No. 2: WAU RD ≥ 25, SOMU RD ≥ 25	Forecast target of 80% of UPLANDS area in each watershed (WAU) that has Relative Density ≥ 48 Thinning Group No. 1: WAU RD ≥ 48, SOMU RD ≥ 25 Thinning Group No. 2: WAU RD ≥ 25, SOMU RD ≥ 25	Forecast target of 80% of UPLANDS area in each watershed (WAU) that has Relative Density ≥ 48 Thinning Group No. 1: WAU RD ≥ 48, SOMU RD >= 25 Thinning Group No. 2: WAU RD ≥ 25, SOMU RD ≥ 25
Visual management	No specific constraint for general visual area Tiger Mtn - constain regeneration harvest to no more that 1/6 (600 acres) of each Watershed Administrative Unit (WAU) per decade and harvest age of at least 60 years.	Regenerate visual area with 20 trees acre (R2). Constrain regeneration harvest to 40 years or more. Tiger Mtn - constrain regeneration harvest to no more that 1/6 (600 acres) of each Watershed Administrative Unit (WAU) per decade and harvest age of at least 40 years.	Regenerate visual area with 20 trees acre (R2). Constrain regeneration harvest to 40 years or more. Tiger Mtn - constrain regeneration harvest to no more that 1/6 (600 acres) of each Watershed Administrative Unit (WAU) per decade and harvest age of at least 40 years.
Hydrological maturity (watershed systems) for Lake Tahuya	Target forecast of hydrological maturity (RD ≥ 25) of at least 66% of inventory area in Lake Tahuya Basin	N/A	N/A
Older forest targets	As per current procedure. All forest stands that meet at least FDS 4 or better are constrained from regeneration harvest. 12.5% of total area that is NDS + FFS are targeted.	As per current procedure. All forest stands that meet at least FDS 4 or better are constrained from regeneration harvest. 12.5% of total area that is NDS + FFS are targeted.	As per current procedure. All forest stands that meet at least FDS 4 or better are constrained from regeneration harvest. 12.5% of total area that is NDS + FFS are targeted.

7.3   Representing Future Forest Condition

7.3.1 Forest Development Stages

Future forest conditions are represented using a classification of forest stand development stages. Forest ecosystems can be explained in terms of their composition, function and structure (Franklin et al 2002, Bormann and Likens 1979). Composition refers to the variety of organisms or species found in forests. Function refers to the "work" carried out by the ecosystem, such as primary productivity or providing wildlife habitat. Forest structure refers to the measureable physical attributes of forests which affect forest function, such as; size and number of trees; number of vertical canopy layers; amount of snags and down woody debris (Franklin et al 2002, Carey 2007). Forest structure provides a readily-measured surrogate for

ecosystem functions that are otherwise difficult to measure directly, and also can be used to assess a forest's value in terms of products or services provided (DNR 2004 Appendix B-31).

Table C26. Forest stand development stages

Stand Development Stages		Forest Development Stage Index (FDS)
EIS	Ecosystem initiation stage	1
CES	Competitive exclusion stage	2
UDS	Understory development stage	3
BDS	Botanical diversity or biomass accumulation stage	4
NDS	Niche diversification stage	5
FFS	Fully functional stage	6

Forest stand development stages were modeled using FVS Keyword StrClass based on Crockson and Stage (1999) stand structure statistics, number of large trees, an old-growth condition index (OFC index), number of large snags, and amount of down woody debris.

The older forest condition index (OFCI) was developed from the 24 high potential old growth stands (WOGHI score greater than or equal to 60) in the South Puget Sound HCP Planning unit. For these stands, a diameter distribution index procedure was developed, similar to a Berger-Parker index[7], and a diameter index score of 20 or greater was determined to represent the diameter distribution of older forests in the South Puget planning unit. The index procedure was calculated as a yield variable for all the strata, in all periods under all treatments.

The computation of the older forest condition index (OFCI) is as follows:

$$
\begin{aligned}
OFCI = {} & Min(Max(Int(TPA_1-507.3698)+1,0),1) \cdot Min(Max(Int(1966.4251-TPA_1)+1,0),1) + \\
& Min(Max(Int(TPA_2-49.1553)+1,0),1) \cdot Min(Max(Int(190.5374-TPA_2)+1,0),1) \cdot 2 + \\
& Min(Max(Int(TPA_3-17.1190)+1,0),1) \cdot Min(Max(Int(66.3246-TPA_3)+1,0),1) \cdot 4 + \\
& Min(Max(Int(TPA_4-15.5868)+1,0),1) \cdot Min(Max(Int(60.3984-TPA_4)+1,0),1) \cdot 8 + \\
& Min(Max(Int(TPA_5-10.4915)+1,0),1) \cdot Min(Max(Int(40.6998-TPA_5)+1,0),1) \cdot 16
\end{aligned}
$$

where TPA_i (i = 1, 2, ..., 5) is the number of trees per acre in the DBH class i.

Table C27. Lower and upper bounds of tree densities (TPA) by diameter class used in the older forest condition index

Diameter Class	DBH (inches)			Trees per Acre (TPA)			Weight
1	0.0 ≤	DBH <	3.5	507.4 ≤	TPA ≤	1,966.4	1
2	3.5 ≤	DBH <	11.5	49.2 ≤	TPA ≤	190.5	2
3	11.5 ≤	DBH <	19.5	17.1 ≤	TPA ≤	66.3	4
4	19.5 ≤	DBH <	29.5	15.6 ≤	TPA ≤	60.4	8
5	29.5 ≤	DBH		10.5 ≤	TPA ≤	40.7	16

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[7] The Berger-Parker index expresses the proportional abundance of the most dominant species or class.

Table C28. Parameters used to model forest development stage (FDS)

Code	Label	FDS name	FVS StrClass	TPA30	OFCI	SNAG20	CWD (ft³/ac)
0	BG	Bare Ground	Less than 5 percent crown cover and fewer than 200 trees per acre				
1	EIS	Ecosystem Initiation	Less than 5 percent crown cover and greater than or equal to 200 trees per acre, or one stratum with a nominal dbh. less than 5 inches; a stratum must have more than 5 percent crown cover to be considered a valid stratum).				
2	CES	Competitive Exclusion	One stratum with an nominal dbh. between 5 and 25 inches. This classification is changed to *ecosystem initiation* if the stand density index is below 30 percent of the maximum allowed for the stand.				
3	UDS	Understory Development	Two strata with the uppermost having a dbh between 5 and 25 inches				
4	BAS	Biomass Accumulation	Two strata with the uppermost having a dbh. between 5 and 25 inches	≥ 15			
					≥ 20		
5	NDS	Niche Diversification	Two strata with the uppermost having a dbh. between 5 and 25 inches	≥ 15		≥ 1.5	≥ 1200
					≥ 20		
6	FFS	Fully Functional	Two strata with the uppermost having a dbh. between 5 and 25 inches	≥ 15	≥ 20	≥ 1.5	≥ 1200

Note: *For the BAS, NDS, and FFS forest development stages, either of the 2 strata meet the FDS definition criteria*
TPA30 = Live trees per acre with DBH ≥ 29.5"
OFCI = Old Forest Condition Index
Snag20 = Snags per acre with diameter ≥ 19.5" and length ≥ 16'

7.3.2 Northern Spotted Owl Future Habitat

The forecasted habitat class is derived from the projected forest condition. The forest condition changes over time due to natural stand dynamics and through silvicultural management events such as thinning, regeneration harvesting, and planting. The change in habitat quality over time (represented by the habitat index HABI) is reflected in the yield tables for the corresponding forest type, site quality, and silvicultural regime.

The Habitat Index values were derived from structural and composition characteristics modeled within FVS. The values for each habitat type are outlined below in Table C29.

Table C29. Northern spotted owl habitat index by habitat class

Northern Spotted Owl Habitat Class	Composite Habitat Index (HABI)	
	Min	Max
None (N)	0	0
Dispersal (D)	1	1
Young Forest Marginal (YFM)	2	3
Sub-mature (S)	4	7
Movement, Roosting, & Foraging MoRF)	8	15
Type B	16	31
Type A	32	63
High Quality Nesting (HQN)	64	127
Nesting, Roosting, & Foraging (NRF)	4	127

Note: NRF equivalent to sub-mature habitat and above

Table C30. Threshold values for northern spotted owl habitat classification and calculation of habitat index (HABI)

Variables	Dispersal	Young Forest Marginal	Sub-mature	Habitat MoRF	Type B	Type A	High Quality Nesting
Number of Tree Species					≥ 2	≥ 2	
Number of Canopy Layers				≥ 2	≥ 2	≥ 2	
Top Height	≥ 85	≥ 85	≥ 85	≥ 85			
QMD100	≥ 11						
RD3d5	≥ 48	≥ 48	≥ 48	≥ 48	≥ 48	≥ 48	≥ 48
TPA3d5		≥ 115 & ≤ 280	≥ 115 & ≤ 280	≥ 115 & ≤ 280			
TPA20					≥ 75 & ≤ 100		
TPA21							≥ 31
TPA30							
TPA30						≥ 15 & ≤ 75	
TPA31							≥ 15
(Conifer TPA3d5) / TPA3d5		≥ 0.3	≥ 0.3	≥ 0.3			
SNAG15				≥ 3.0			
SNAG20		≥ 2.0*	≥ 3.0		≥ 1.0		
SNAG21							≥ 12
SNAG30						≥ 2.5	
CWD (ft^3/ac)		≥ 4800*	≥ 2,400	≥ 2,400	≥ 2,400	≥ 2,400	≥ 2,400
Habitat value (n)	0	1	2	3	4	5	6
If all conditions are met, then binary value = 1, else 0. Habitat Index (HABI) = (2 x binary value)^n	1	2	4	8	16	32	64
Maximum composite HABI (sum of all habitat types that exist simultaneously)	1	3	7	15	31	63	127

Note: YFM habitat, either condition (*) meets the criteria

An analysis of growth and yield data using the above habitat classifications revealed a pattern of discontinuous or irregular habitat development over time (Figure C6), a result which partially stems from the technique of assigning a given forest condition to a single habitat class. The habitat classifications were applied using "crisp logic". Under that doctrine, a member either does or does not belong to a set; there is no middle ground. For example, sub-mature habitat relative density is defined as greater than or equal to 48 (RD3d5 ≥ 48). Stands with a relative

density less than 48 were not classified as sub-mature habitat. In contrast, in "fuzzy logic:, set membership is not binary, but instead ranges on a scale from 0 to 1.

Moreover, all of the conditions must be satisfied in order for a stand to meet a given habitat class. For example, stands classified as submature habitat must meet all the requirements for top height, relative density, trees per acre, conifer percent, snag, and down woody debris. Failure to meet any one of these requirement will exclude the stand from the sub-mature habitat classification.

This approach to habitat classification results in irregular habitat yields under no-treatment (UT) and thinning projections (1CT, 1MT, 1AT) (Figure C6). Of 42 strata yield sets (representing 70 percent of the land base), 15 were found to have discontinuous habitat yields. This represents roughly 25 percent of the South Puget HCP Planning Unit land base (approximately 36,000 ac; 14,500 ha).
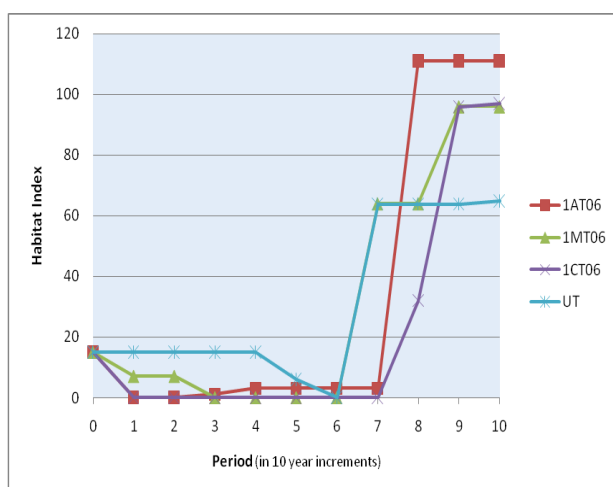
Figure C5. Discontinuous habitat yields for strata DFWH-SIC2-MISTK-SIZE3 under different thinning treatments. UT = unthinned; 1CT06 = first commercial thinning at age 60; 1MT06 = first Movement, Roosting, & Foraging (MoRF) and sub-mature thinning at age class 60; 1AT06 =first thinning for the creation of Type A and older forest habitat at age class 60.

Further analysis of the yield tables illustrated the difficulty in representing the maintenance of habitat after a thinning treatment. This was especially true for sub-mature habitat as illustrated in Table C31 below, where an insufficient number of live trees per acre ≥ 3.5 inches dbh are maintained over time to meet the requirements for that habitat class (Figure C7), and there is an insufficient number of large trees per acre to qualify for Type A or B habitat.

Table C31. Habitat yields for strata DFWH-SIC2-MISTK-SIZE3 under selected treatments.

Age Class	Heavy VDT in period 1 (1AT06)	Heavy VDT in period 2 (1AT07)	Light VDT in period 1 (1MT06)	Light VDT in period 2 (1MT07)	Unthinned (UT)
50	Non-habitat	Non-habitat	Sub-mature	Non-habitat	MoRF
60	Non-habitat	Non-habitat	Sub-mature	Sub-mature	MoRF
70	Dispersal	Non-habitat	Non-habitat	Sub-mature	MoRF
80	YFM	Dispersal	Non-habitat	Non-habitat	MoRF
90	YFM	MoRF	Non-habitat	Non-habitat	Sub-mature
100	YFM	Type A	Non-habitat	Non-habitat	Non-habitat
110	YFM	HQNH	HQNH	HQNH	HQNH
120	HQNH	HQNH	HQNH	HQNH	HQNH
130	HQNH	HQNH	HQNH	HQNH	HQNH
140	HQNH	HQNH	HQNH	HQNH	HQNH
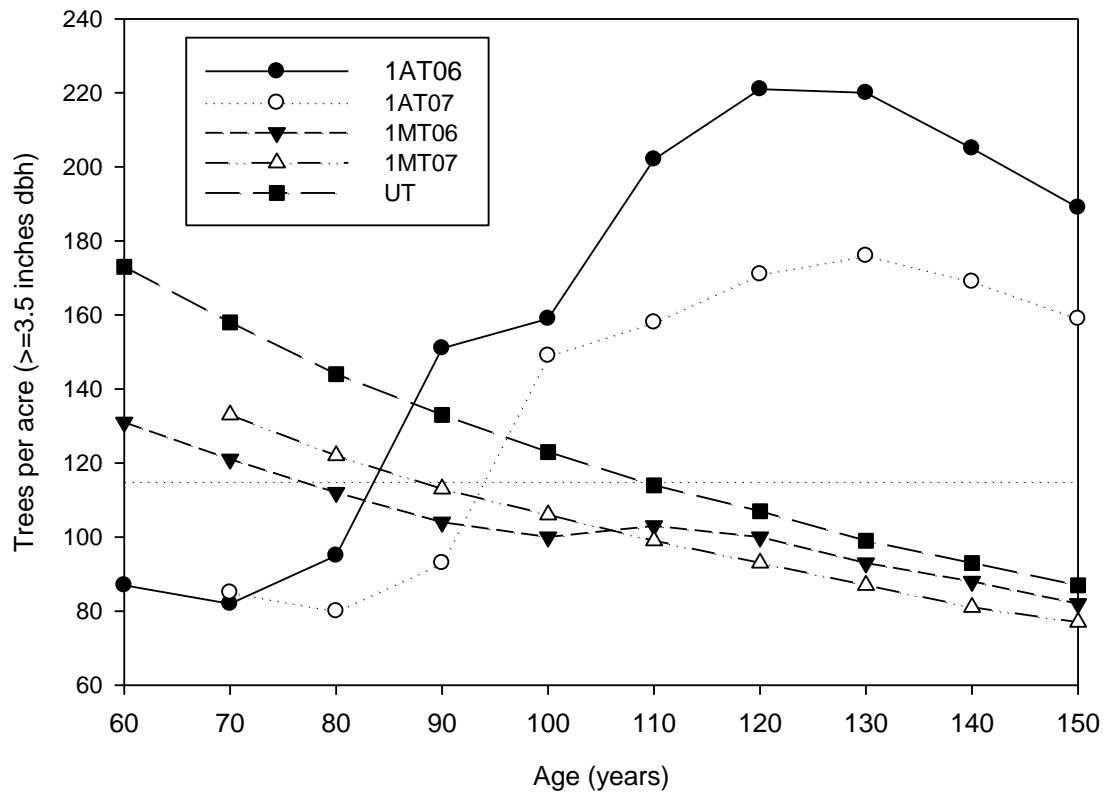
Figure C6. Projected number of trees per acres ≥ 3.5 inches dbh for strata DFWH-SIC2-MISTK-SIZE3 under selected treatments. 1AT06 = heavy VDT in period 1; 1AT07 = heavy VDT in period 2; 1MT06 = light VDT in period 1; 1MT07 = light VDT in period 2; UT = unthinned. Lower threshold for sub-mature habitat (≥ 115 & ≤ 280 trees per acre ≥ 3.5 inches dbh) shown as dotted line.

8.   REVISIONS

The following revisions have been made to the model since completion of the initial computer modeling for the draft EIS analysis

- The South Puget HCP Planning Unit and DNR administrative regions were integrated for the purposes of applying 2007 sustainable harvest calculation volume targets..
- The number of modeling themes was increased from 10 to 13 for improved transparency and flexibility. One of the original themes was split, and two new themes were added. The *watershed* theme, originally containing both WAU and SOMU data, was split into two themes. An *administrative unit* theme was added containing boundaries for counties, DNR regions, districts, locals, and HCP Planning Units. A *harvest access* theme was added.
- Financial data and calculations were revised. A royalty premium was applied to Tahuya stumpages to reflect higher wood quality. A volume yield discount was used to address lower growth rates.
- In the initial computer modeling, all harvesting options (CT, AT, MT, R1, R2) were permitted for Alternatives B and C. For Alternative A harvesting options R0 and AT were excluded and MT was only permitted in concurrence letter areas. In the revised model, the range of permissible, restricted and prohibited silvicultural options were standardized across the Alternatives. Permissible options include CT, AT and MT and R1. The R2 option is restricted for visual areas. R0 is prohibited on all sites.
- In Alternative A, 50% of each SOMU must be maintained as mapped dispersal habitat until 2014. After 2014, only the forecasted dispersal habitat must be maintained at the 50% threshold.
- Thinning specifications were modified in settlement and concurrence letter areas.
- Ending period inventory controls were added to ensure continued reinvestment in silviculture and the maintenance of growing stock at the planning horizon. Without such controls, the objective of the linear programming model to maximize net present value would result in a harvest rate in excess of growth rate.
- Upland Management targets were redefined such that areas in Thinning Group 1 (Belfair, Hoodsport, Snoqualmie (Tiger Mountain), Black Hills, Boulder) can be thinned to a relative density of of 48, while areas in Thinning Group 2 (Elbe-Hills and Black Diamond) can be thinned to a relative density of 25.

The collective impacts of these changes are described in the following section. A discussion of the original and revised modeling results and a corresponding series of figures follow..

8.1   Wood Supply Forecast

The original wood supply forecast for the Draft EIS exhibited an upward long-term trend in harvest level resulting from an unconstrained harvest of the ending growing stock (standing volume) in periods 6 through 10. The revised model has been modified to ensure the harvest levels are sustainable by maintaining a non-declining growing stock volume and at least an average level of thinning investment.

Mathematical models have a finite planning horizon. When coupled with an objective function to maximize the net present value (discounted revenues less discounted costs), the model will produce management schedules that increase the harvest, liquidate the growing stock, and limit investments in thinning or other stand improvements towards the end of the planning horizon. This occurs because the model does not receive any benefits (revenue) from holding the existing resource or making investments that will result in a higher future income stream beyond the defined planning horizon. The effect is most pronounced late in the planning horizon; where no return is realized by holding the resource as growing stock. The impact is less pronounced earlier in the planning horizon, as the opportunity cost is less and returns may be realized on some of the silvicultural investments. The pattern will be more pronounced depending on the discount rate and cashflow profiles of the stand (rotation length, growth rates, silvicultural regime). No silvicultural investment will occur when the rate of return is less than the discount rate unless there are no other options and replanting is compulsory, or if forest estate level constraints for a particular log grade or forest habitat condition have a higher shadow price.

The downward trend in sustainable harvest in the revised model is a product of two factors: constraints are imposed to maintain the growing stock, and stringent northern spotted owl habitat targets are specified. The constraints need to be relaxed to converge on a sustainable harvest level that balances these objectives. More refinement in the modeling of the "ending" inventory are being explored between the draft EIS and the final EIS.

8.2   Growing Stock

A progressive increase in the growing stock profiles over the planning horizon is shown in both the original and revised models for the Draft EIS. The overall increase is a result of current HCP Riparian Conservation Strategy objectives, including the Riparian Forest Restoration Strategy. In the model, riparian buffers receive at most a single thinning operation, and are subsequently maintained with no harvest removals. The original Draft EIS forecast showed a significant decline in growing stock during the latter part of the planning horizon resulting from an unconstrained increase in harvest levels and lack of ending inventory requirements (Figure C9).

8.3   Harvest Area

The harvest area profiles reflect the level of wood supply harvested and the permissible silvicultural options. In the original computer modeling for the Draft EIS, all harvesting options (CT, AT, MT, R1, R2) were permitted for Alternatives B and C. For Alternative A harvesting options R0 and AT were excluded and MT was only permitted in concurrence letter areas. In the revised model, the range of permissible, restricted and prohibited silvicultural options were standardized across the Alternatives. Permissible options include CT, AT, MT, and R1. The R2 option is restricted for visual areas. R0 is prohibited on all sites.

The original harvested area forecast for the Draft EIS is characterized by no commercial thinning in the last planning period. As discussed in previous sections, this is due to a lack of silvicultural investments, since the resulting higher future income stream is not realized within the planning horizon and is not included in the calculation of net present value.

Figure C7. Wood supply forecast. Original (top) and revised (bottom).
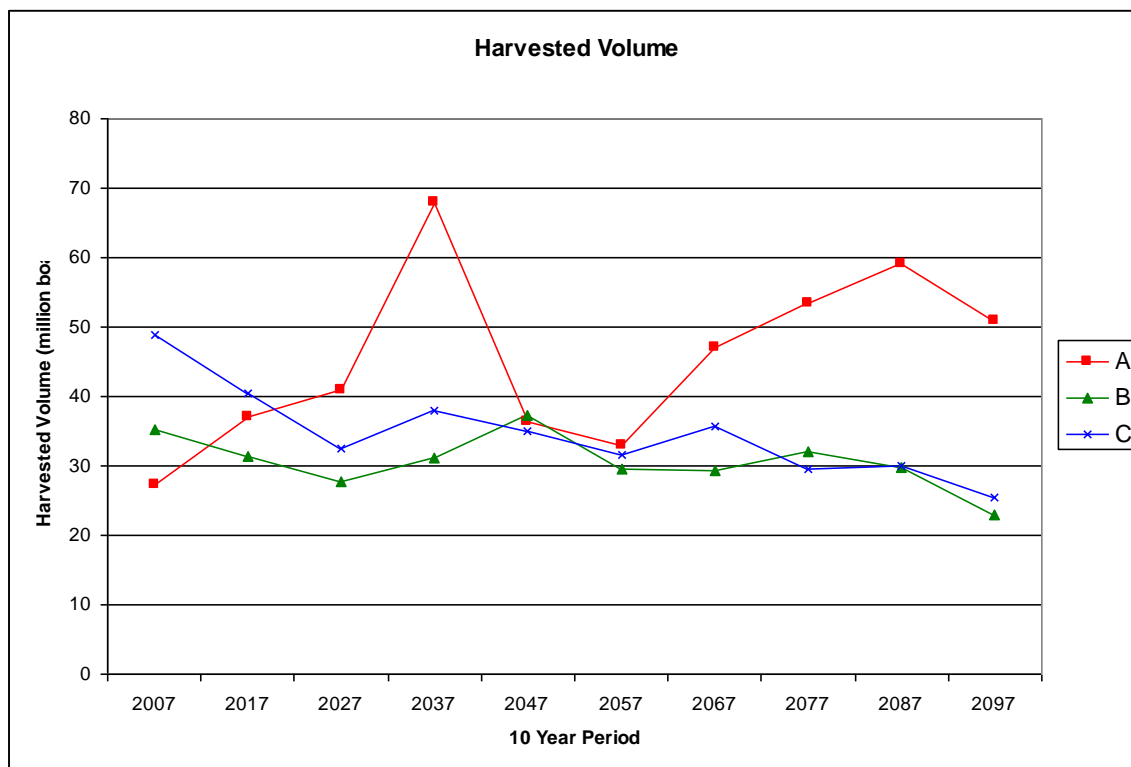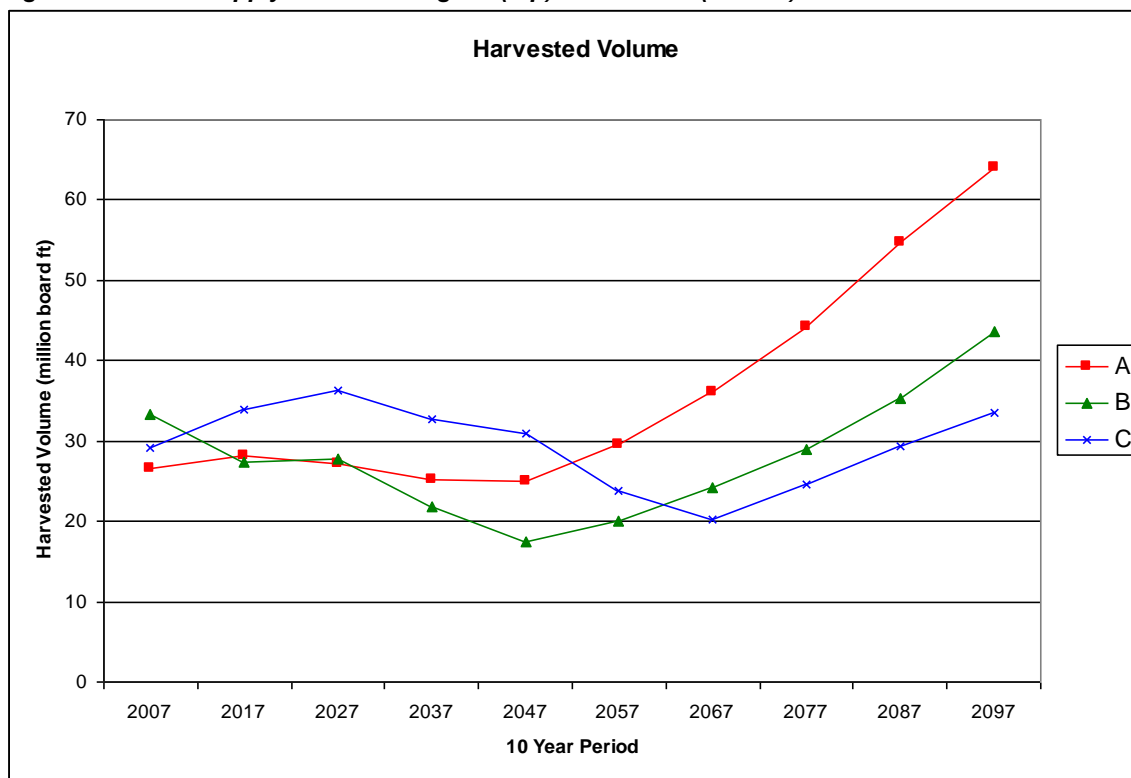
Figure C8. Growing stock. Original (top) and revised (bottom).
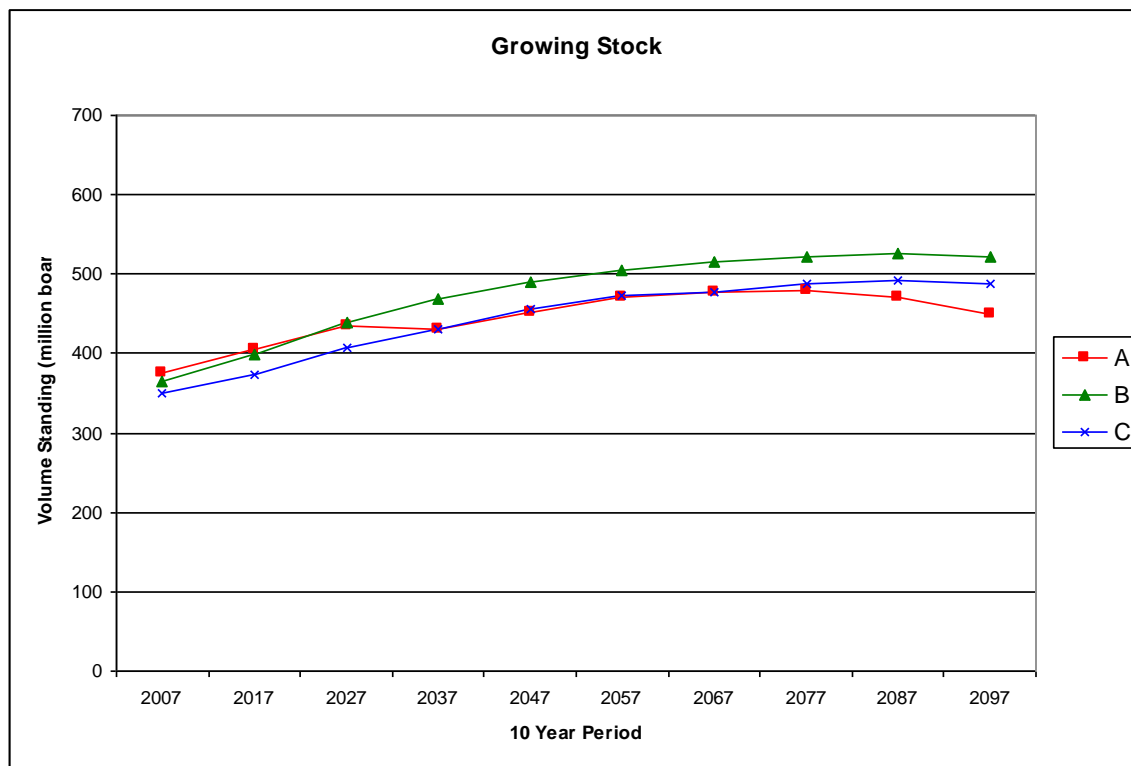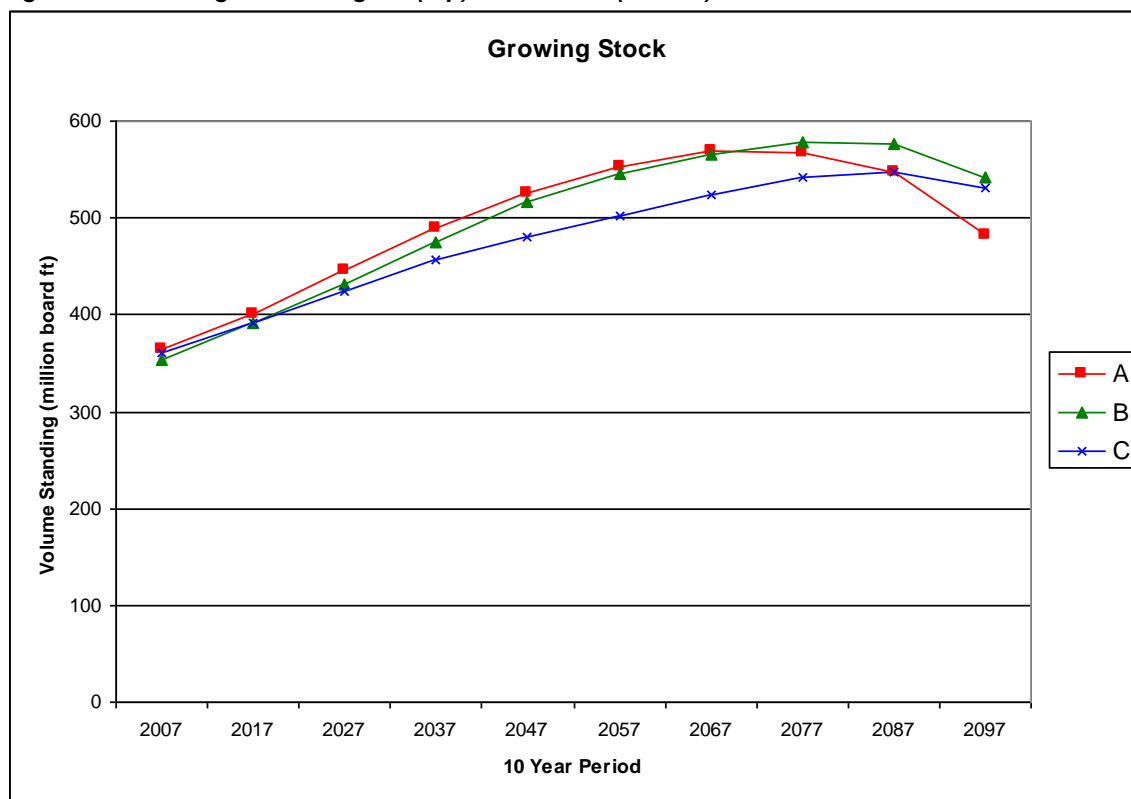
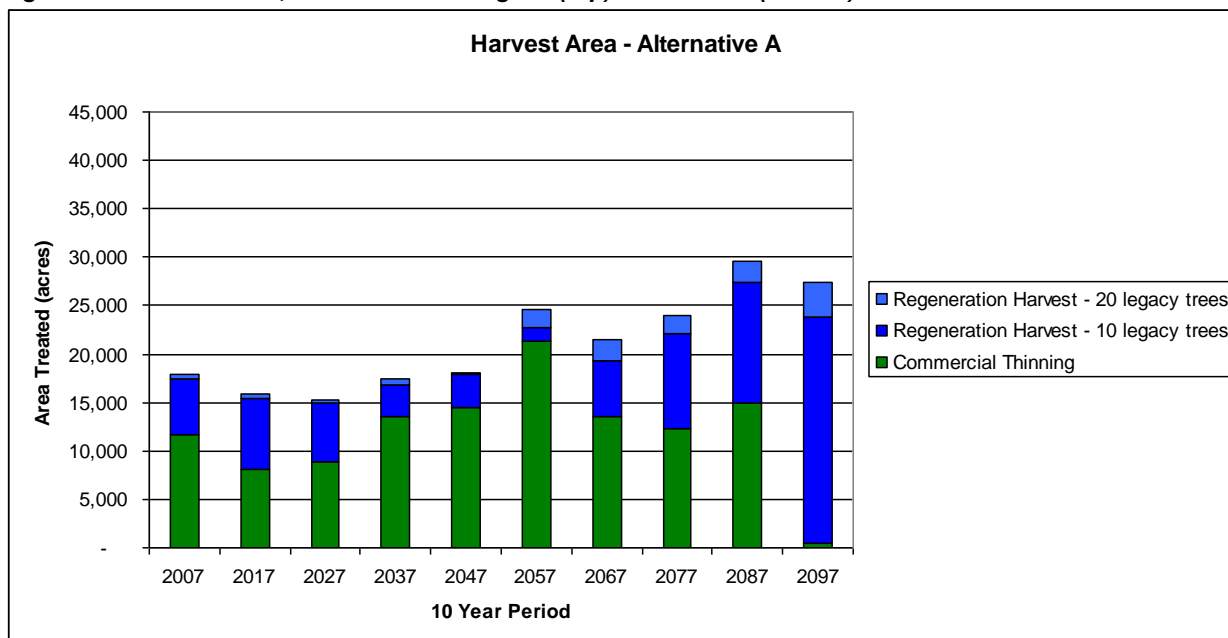**Figure C9. Harvest Area, Alternative A. Original (top) and revised (bottom).**
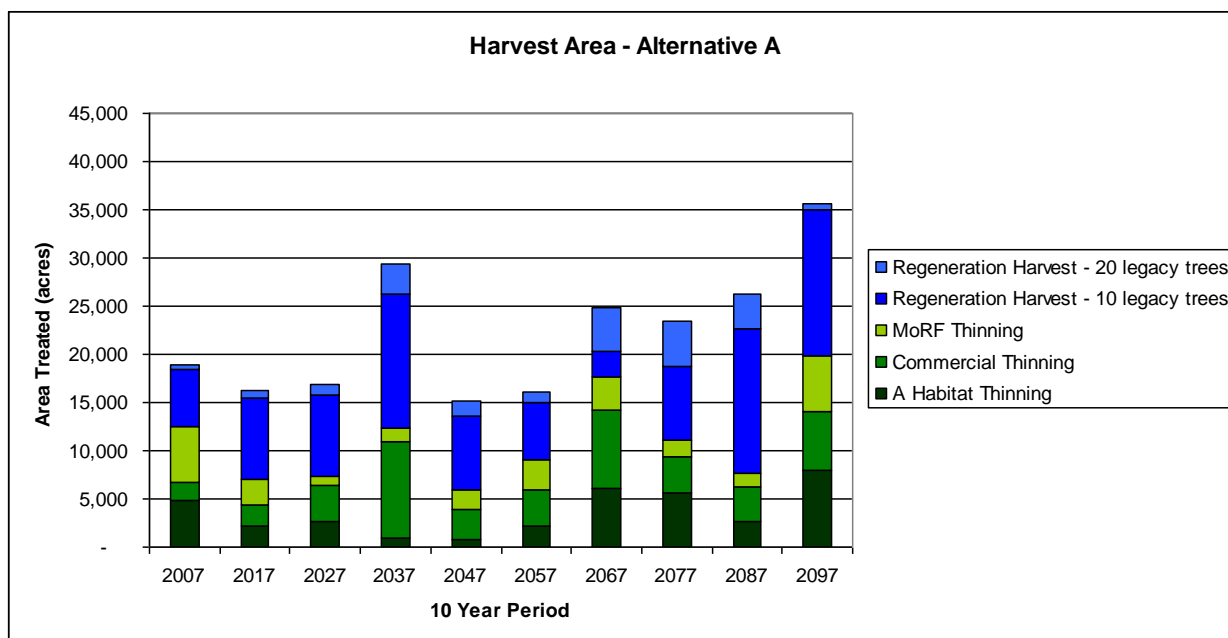
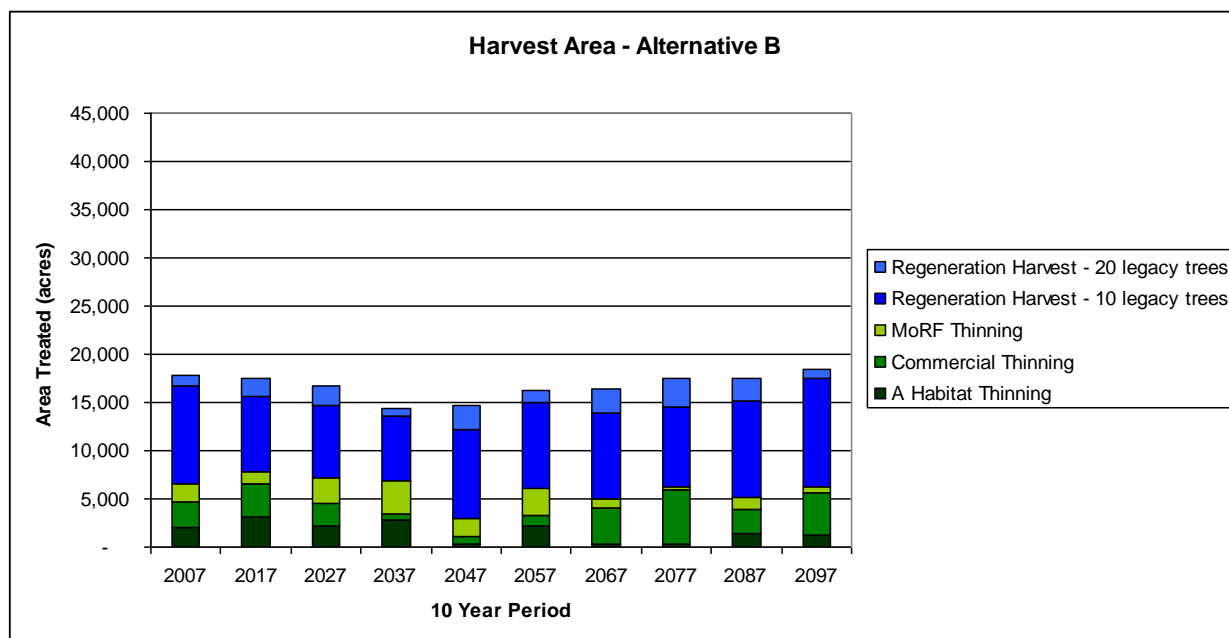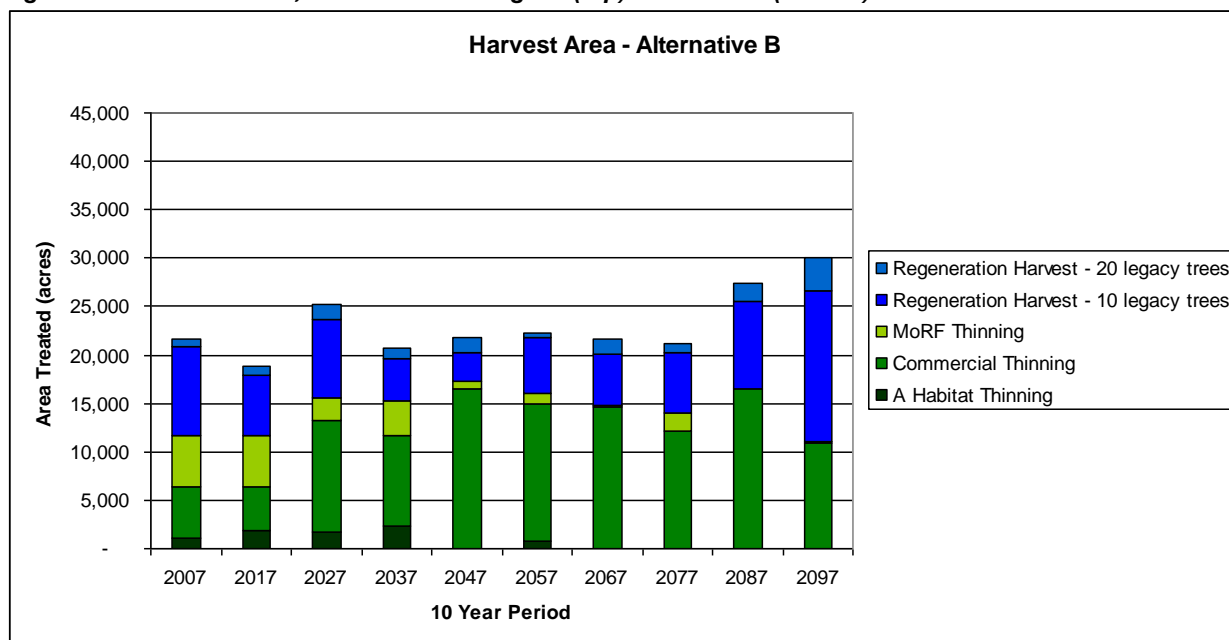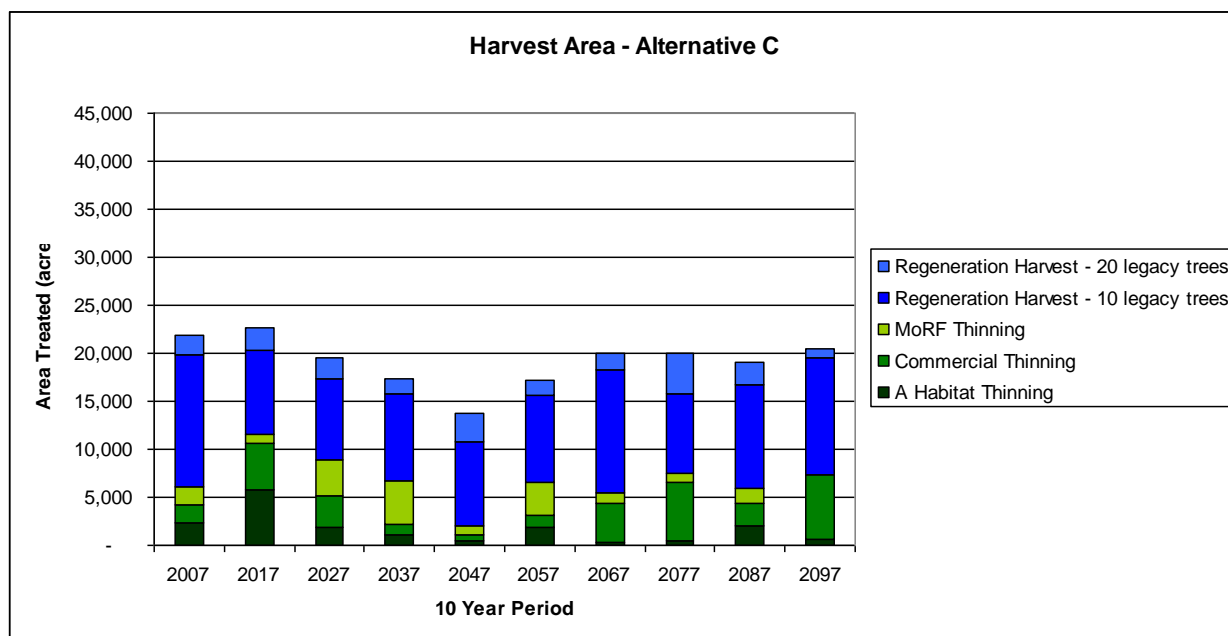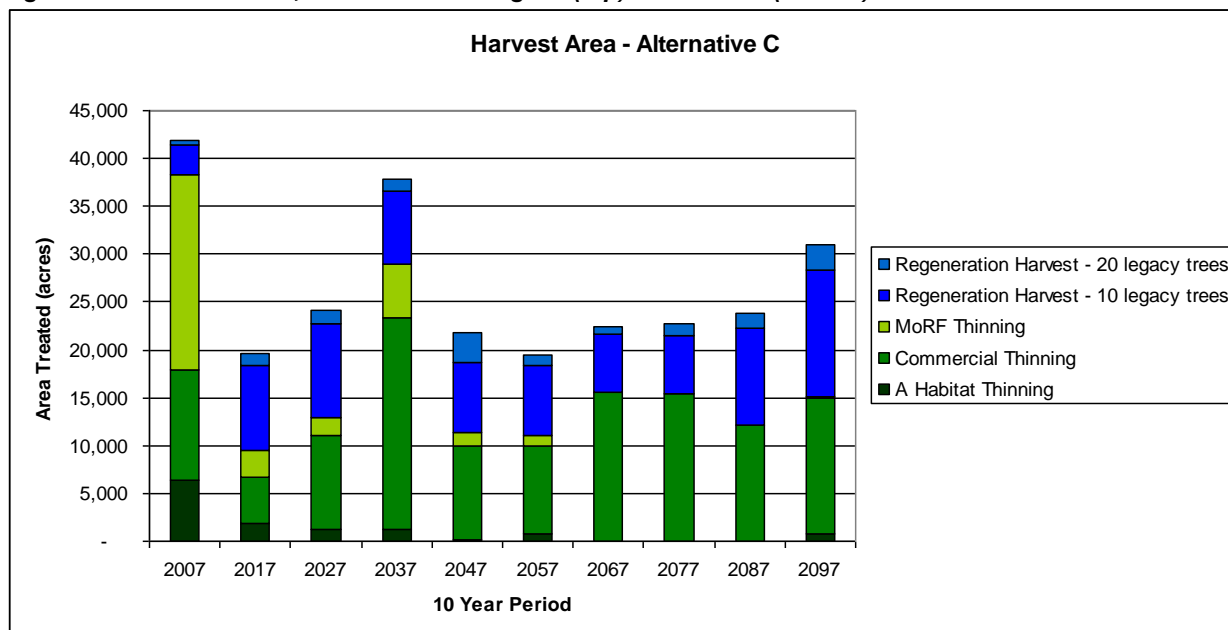**Figure C10. Harvest Area, Alternative B. Original (top) and revised (bottom).**

Figure C11. Harvest Area, Alternative C. Original (top) and revised (bottom).

Harvest Area - Alternative C

Harvest Area - Alternative C

8.4   Sensitivity Analysis of Timber Flow Constraints

The following section describes some sensitivity analysis of timber flow constraints, only applicable to Alternative A. The base area for the analysis includes the combined South Puget HCP Planning unit and the DNR South Puget Sound Region administrative unit. The trends are comparable to other analyses in this report but the magnitude of results are not.

Three timber supply constraints were applied:

1. 10 period minimum volume harvested constraint by county +/- 25% between period (Alternative A)
2. First period minimum volume harvested constraint by county +/- 25% between period
3. First period minimum volume harvested constraint by county +/- 25% between period and +/- 10% variation from first period volume for each DNR District

The objective of modeling only one period minimum volume targets (current sustainable harvest commitments) is to allow the model to determine new harvest levels by location over time that maximize the objective function (Net Present Value). The removal of constraints results in a higher initial harvest but gradual decline in harvest. The addition of a District-level flow constraint removes both total Region and District harvest level variation.

The rationale for imposing a District-level flow constraints include:

- The flow constraint provides District level stability. Harvesting levels affect District staffing requirements for forest management planning and utilization. A stable production environment ensures continuity of a skilled work force and provides assurances in both the location and volume of timber harvests for contractors to make capital investments in harvesting equipment
- Removal of variation in District level harvesting demonstrates long-term sustainability of harvesting to the community.
- Avoiding volatility in production to maintain public expectations and acceptance of externalities such as traffic flows and noise levels.
- Minimizing variation in harvesting traffic flows facilitates planning and investment in county infrastructure such road development and maintenance.
- Modeling based on constrained optimization without consideration of spatial harvest patterns and community costs can result in untenable management plans with limited added value. The above mentioned benefits can be provided at minimal cost.

The impacts on Net Present Value, total harvest, county harvest levels, and District harvest levels are illustrated on the following figures. Comparison of Net Present Value for Alternative A as originally modeled and with 10 period minimum volume constraints provides a measure of the cost of managing the harvest with different flow constraints.

Figure C12. Impact of Timber Flow Constraint on Net Present Value, Alternative A.
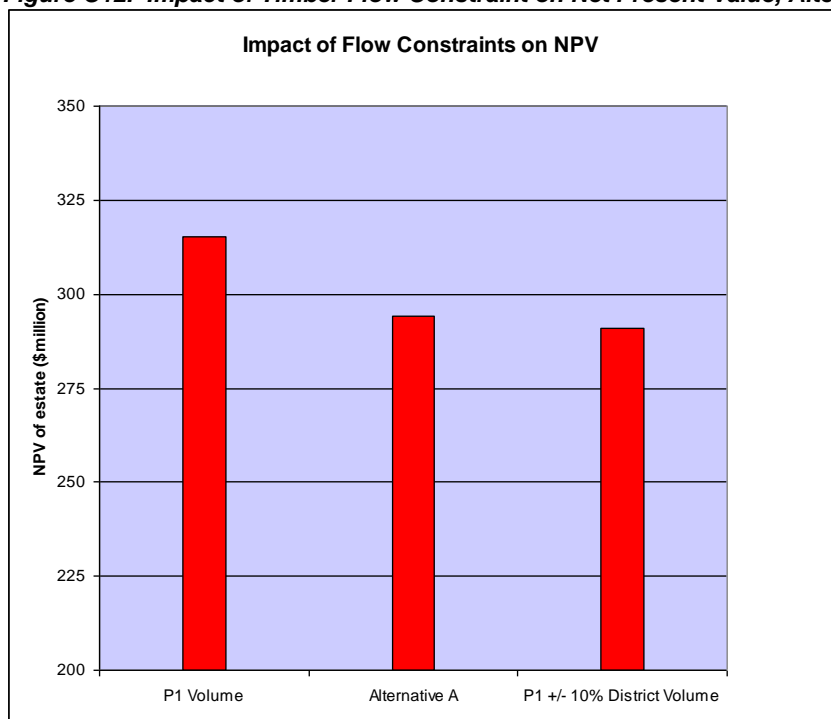
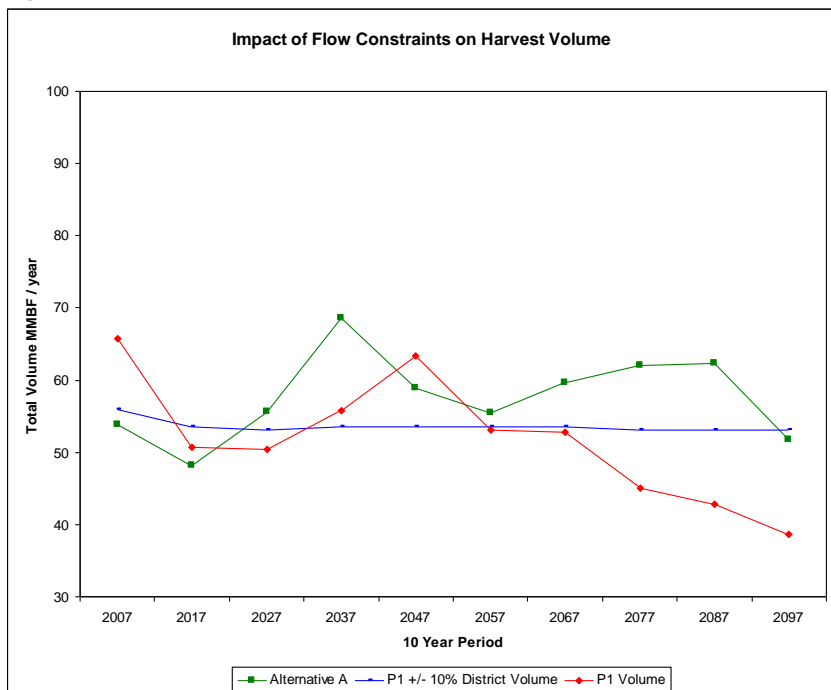*Figure C13. Impact of Timber Flow Constraint on Harvest Volume, Alternative A.*

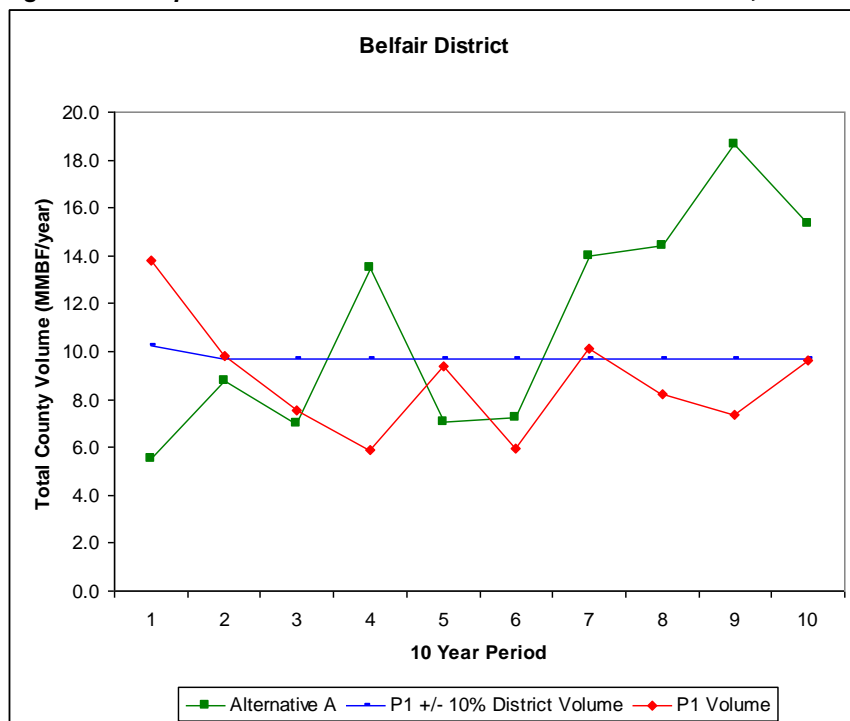*Figure C14. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Belfair District.*

Figure C15. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Black Diamond District.
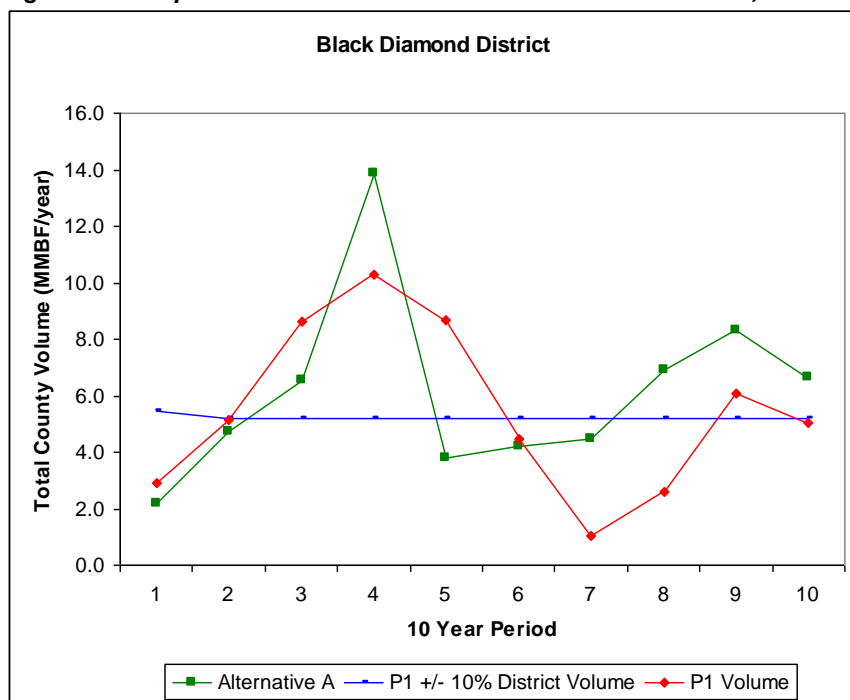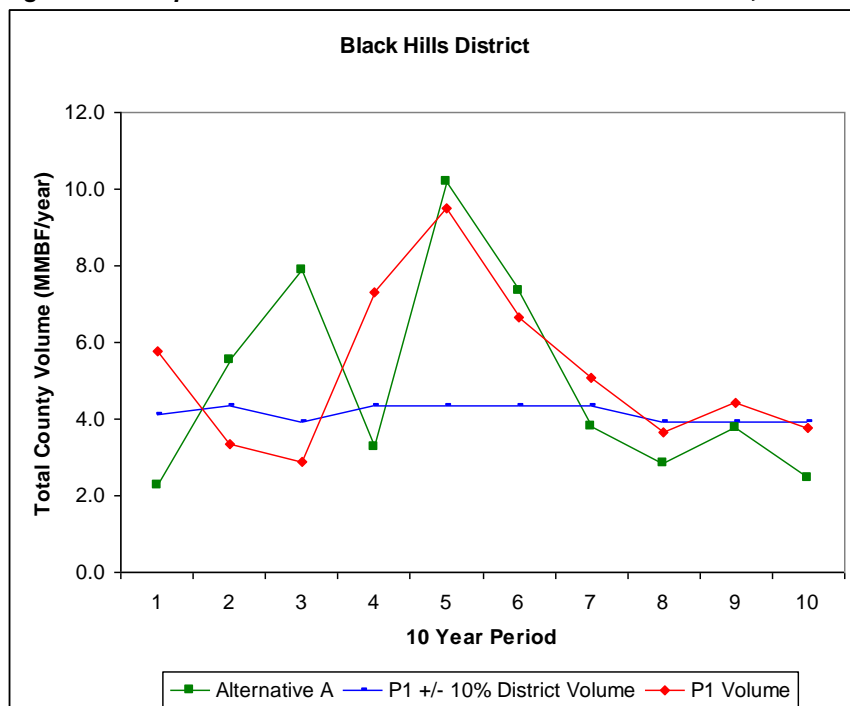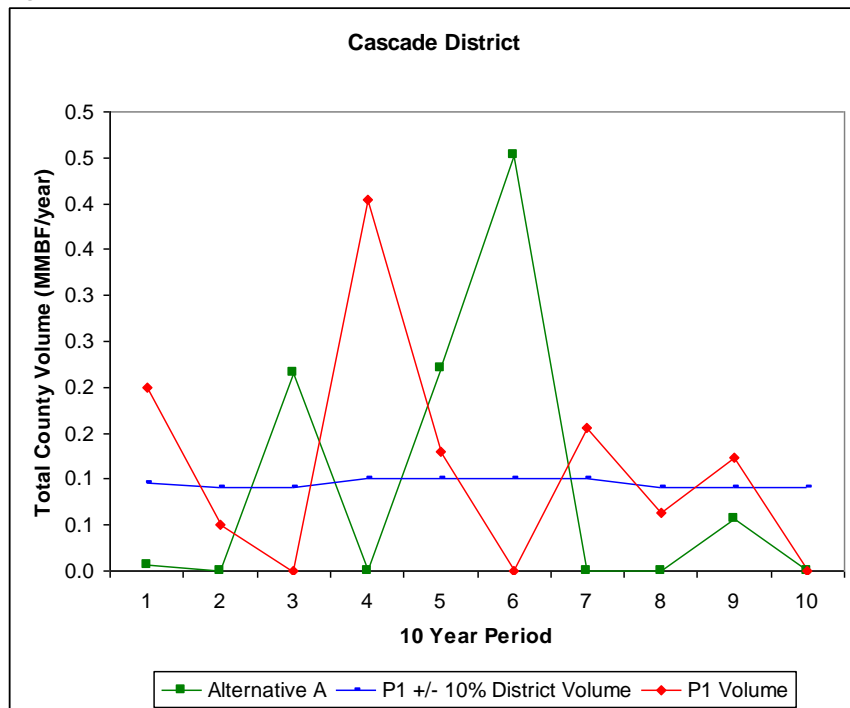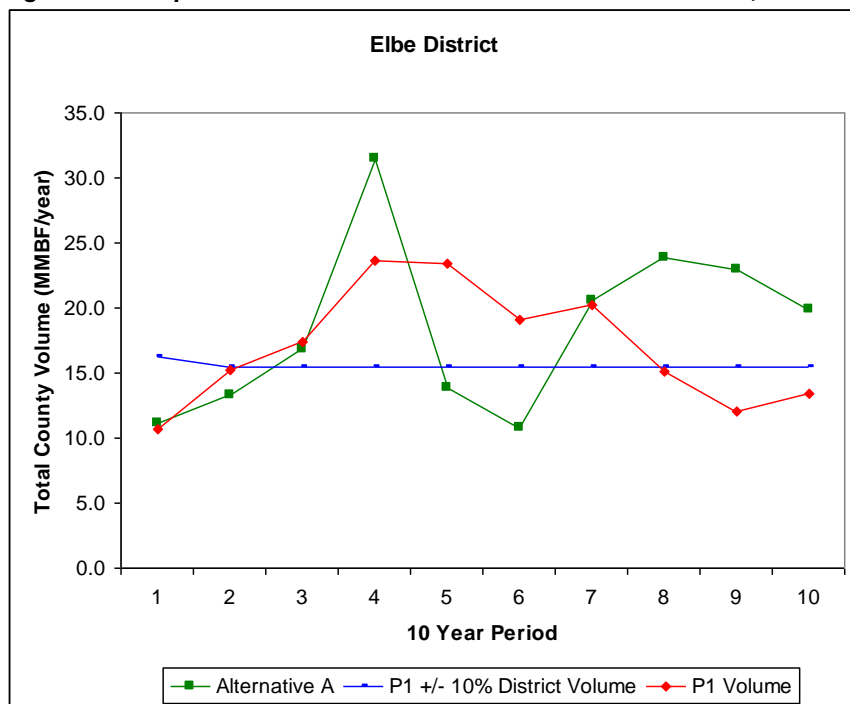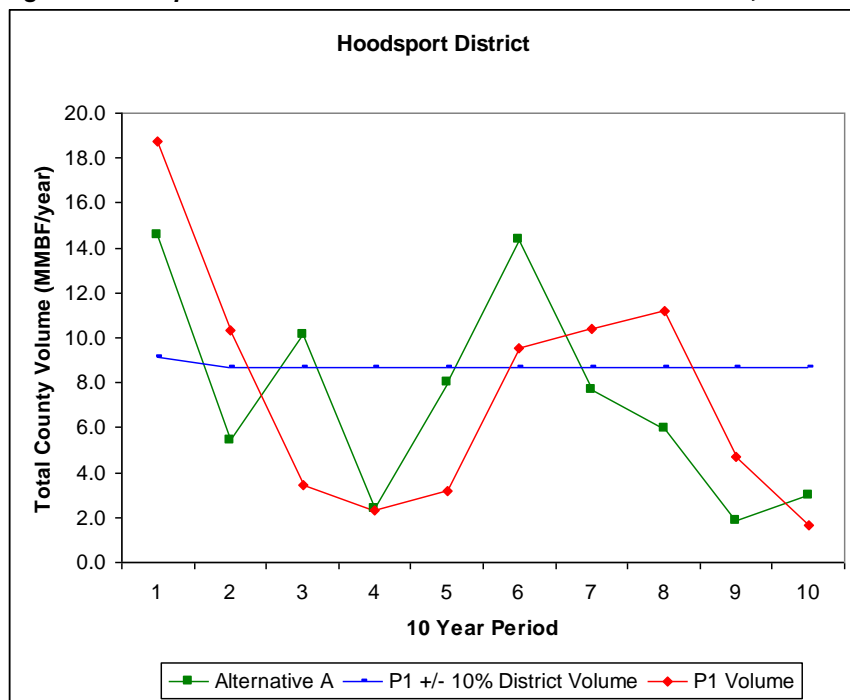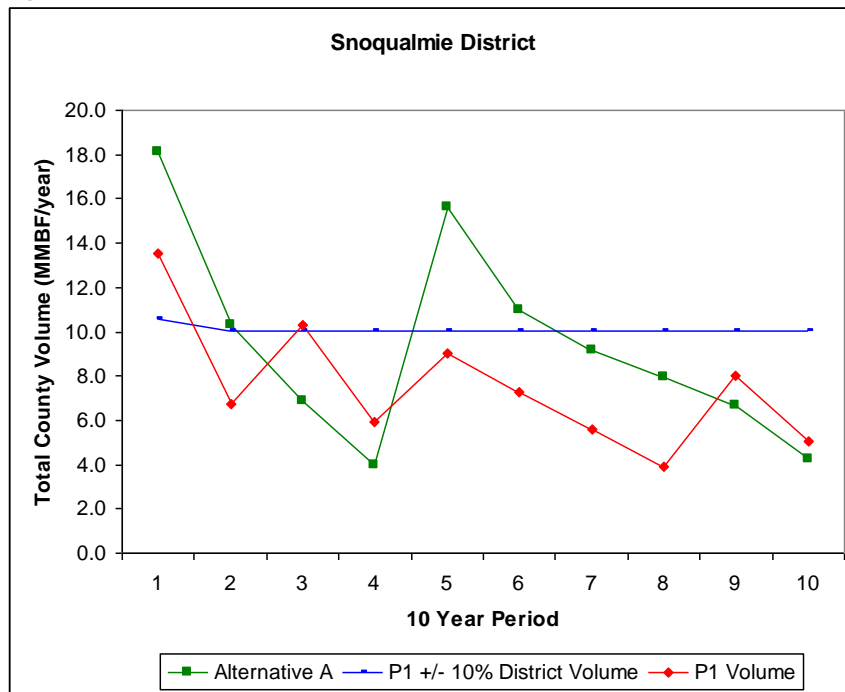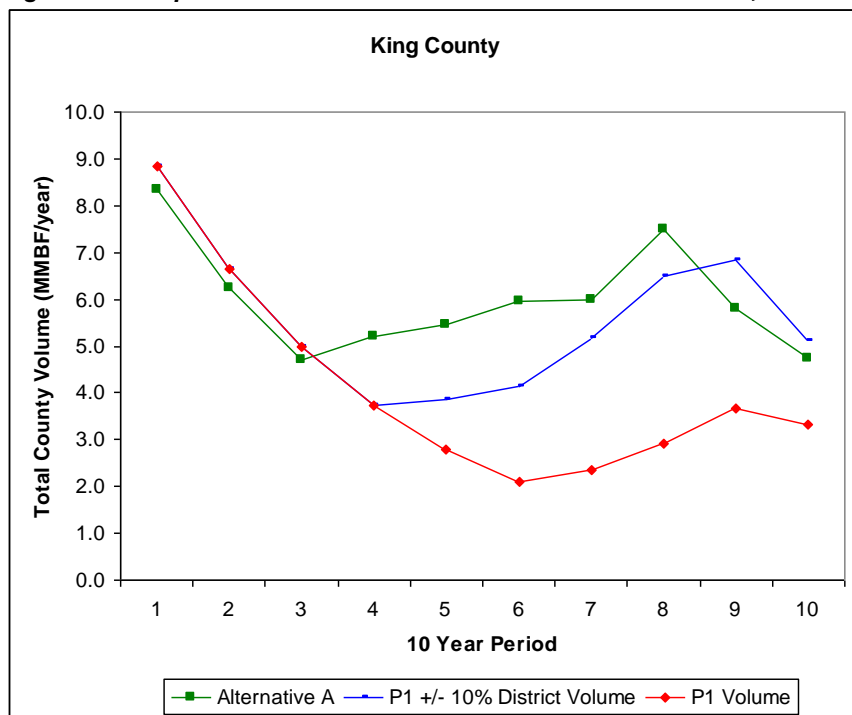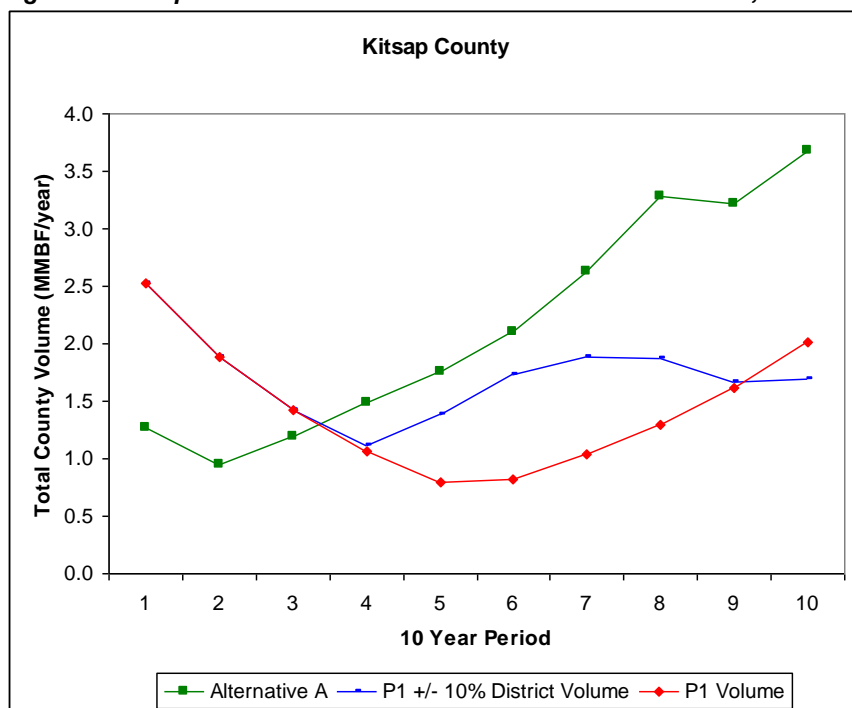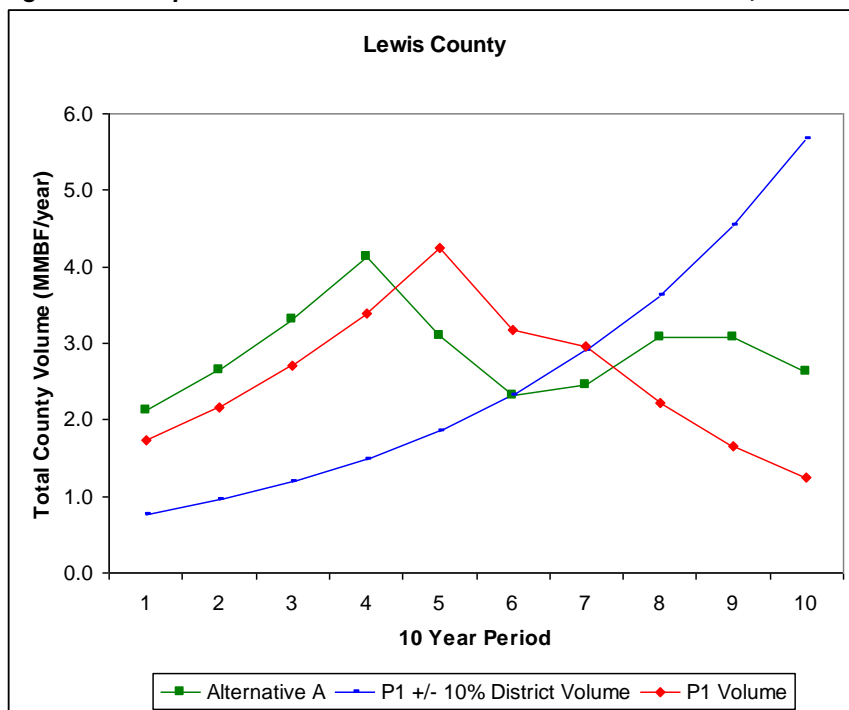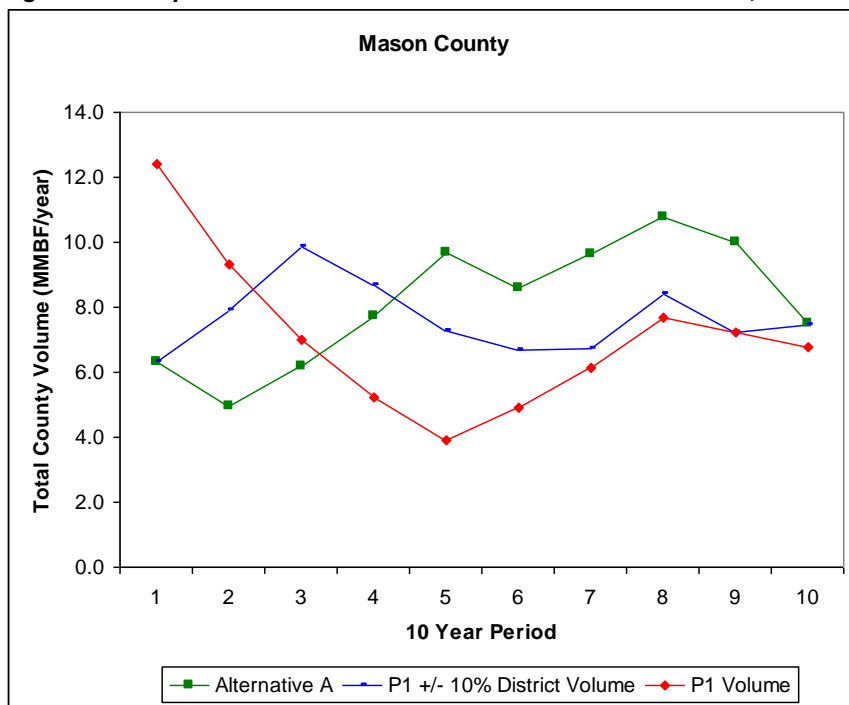
Figure C16. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Black Hills District.

Figure C17. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Cascade District.
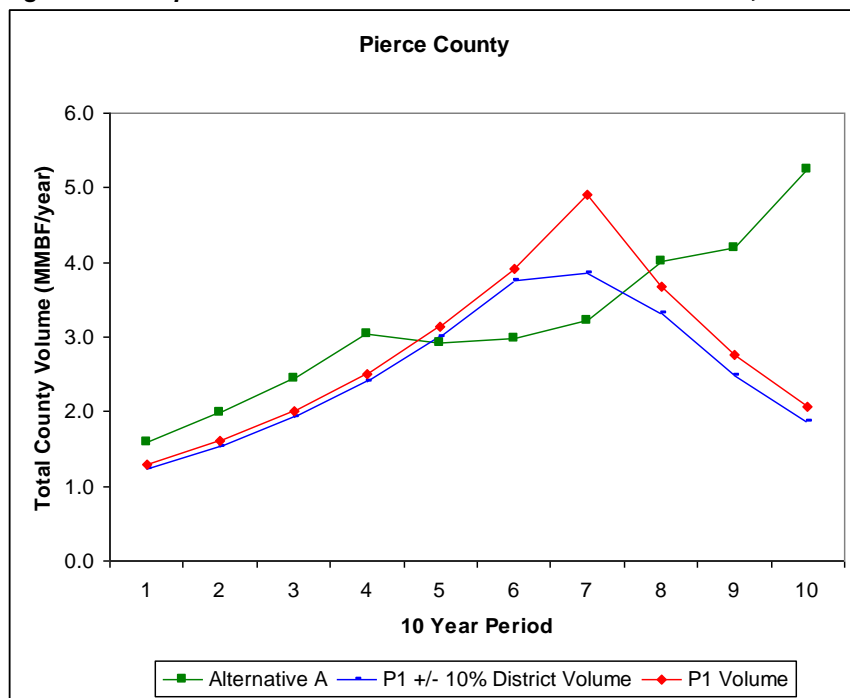
Figure C18. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Elbe District

Figure C19. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Hoodsport District.

Figure C20. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Snoqualmie District.

Figure C21. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, King County.

Figure C22. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Kitsap County.

Figure C25. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Pierce County.

Figure C26. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Snohomish County.
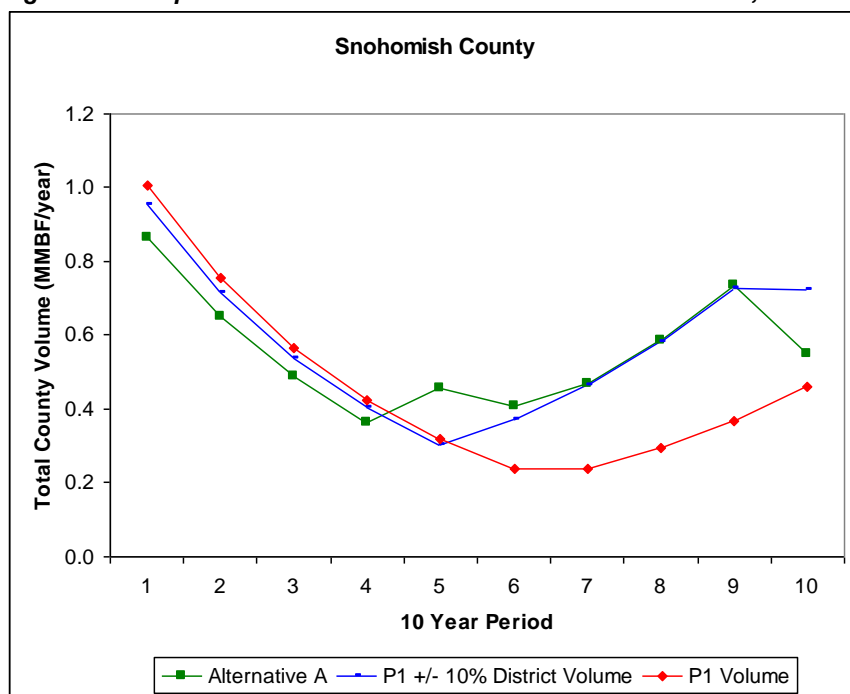
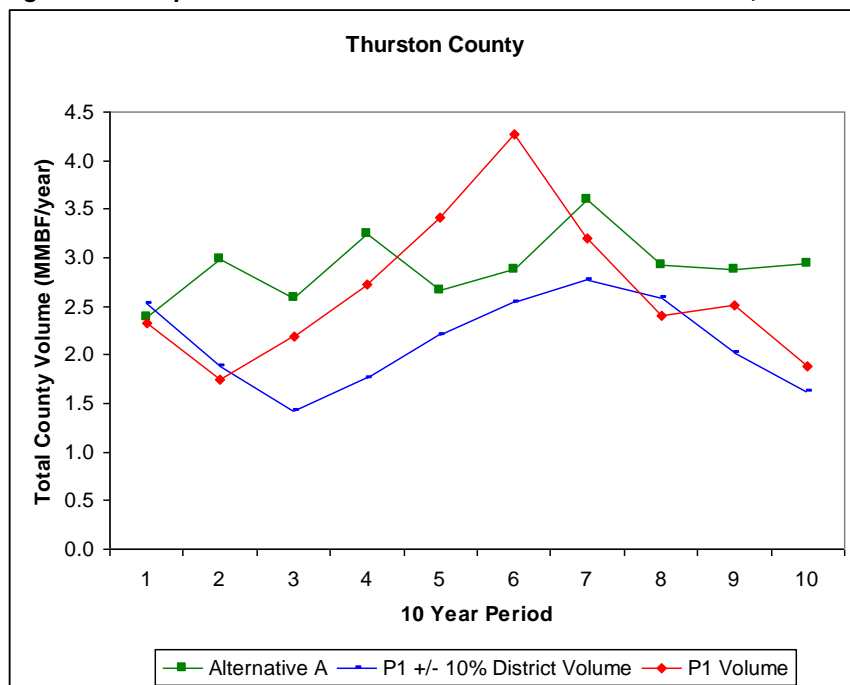**Figure C27. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Thurston County.**
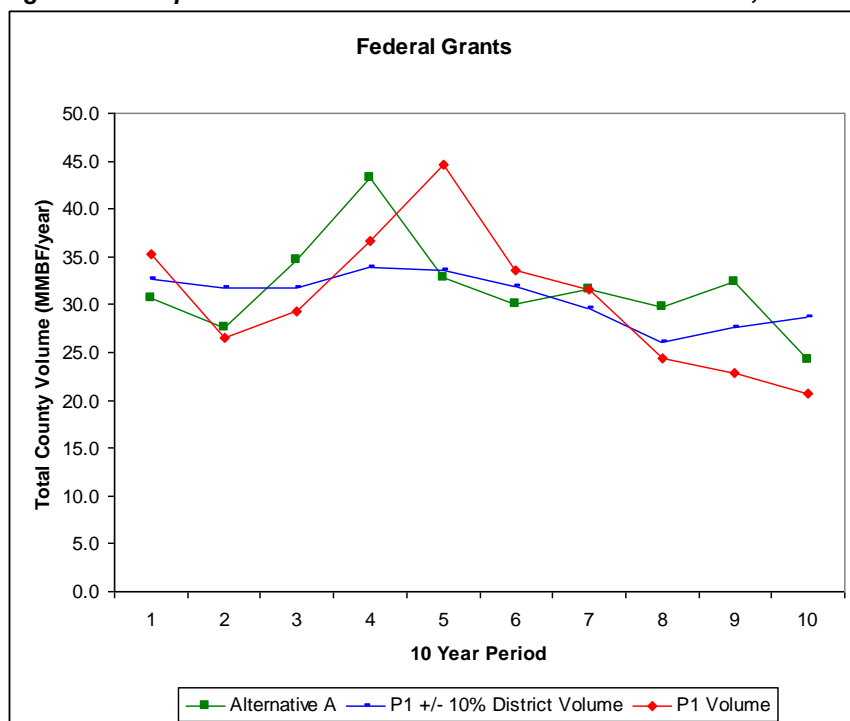

Figure C28. Impact of Timber Flow Constraint on Harvest Volume, Alternative A, Federal Granted Trusts.

9. REFERENCES

Bormann, D.B.; Likens, G.E.. 1979. Pattern and Process in a Forested Ecosystem. New York: Springer-Verlag.

Carey, A.B. 2003. Managing for Wildlife: A Key Component for Social Acceptance of Compatible Forest Management. Pages 401-425 *In*: R.A. Monserud, R.W. Haynes and A.C. Johnson (eds.). Compatible Forest Management. Kluwell Academic Publishers, Norwell, Massachusetts.

Carey, A.B. 2007. Aiming for Healthy Forests: Active, Intentional Management for Multiple Values. USDA Forest Service General Technical Report PNW-GTR-721. Pacific Northwest Research Station, Portland, Oregon.

Crookston, N. and A. R. Stage. 1999. Percent canopy cover and stand structure statistics fromthe Forest Vegetation Simulator. Gen. Tech. Rep. RMRS-GTR-24. Ogden, UT: U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 11 p.

Franklin J.A, D. R. Berg, D.A. Thornburgh and J.C. Tappenier 1997 Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. In Creating a Forestry for the 21st Century: the science of ecosystem management. K.A. Kohm and J.A. Franklin (Eds), Washington D.C. Island Press

Holmberg, P. and B. Aulds. 2007. Developing Westside Silvicultural Prescriptions: an Inter-Active Self Study and Reference Pamphlet. Washington State Department of Natural Resources. Olympia, WA.

Vanclay, J.K., 1994. Modelling Forest Growth and Yield: Applications to Mixed Tropical Forests. CAB International, Wallingford, U.K

Washington State Department of Natural Resources. 2004. Final Environmental Impact Statement on Alternatives for Sustainable Forest Management of State Trust Lands in Western Washington and for Determining the Sustainable Harvest Level. Washington State Department of Natural Resources, Olympia, Washington.

Washington State Department of Natural Resources. 1997. Final Habitat Conservation Plan. Washington State Department of Natural Resources. Olympia, WA.